Thesis/
Reports
Swetnam,
T. W.

# SEVERITY OF WESTERN SPRUCE BUDWORM OUTBREAKS IN SOUTHWESTERN MIXED-CONIFER HABITAT TYPES

by
Dr. Thomas W. Swetnam

# SEVERITY OF WESTERN SPRUCE BUDWORM OUTBREAKS IN SOUTHWESTERN MIXED-CONIFER HABITAT TYPES

Final Report

Contract 28-K7-406

to

U. S. Forest Service
Rocky Mountain Forest & Range Experiment Station
240 West Prospect
Fort Collins, Colorado 80526-2098

by

Dr. Thomas W. Swetnam
Laboratory of Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

January 20, 1989

# INTRODUCTION

Forest entomologists and ecologists have observed that site and tree characteristics influence forest stand susceptibility and vulnerability to western spruce budworms, *Choristoneura occidentalis* Freeman (Carlson et al. 1983). These characteristics include tree species composition, stand density, height structure, tree vigor and maturity, macro- and micro-climate, and surrounding forest types (Wulf and Cates 1985, Wulf and Carlson 1985). The "habitat type" plant community classification scheme (Daubenmire 1968, Pfister and Arno 1980, Moir and Ludwig 1979, DeVelice et al. 1986) reflects a number of these characteristics, particularly species composition and climatic factors.

The objective of this study was to dendrochronologically sample and analyze a set of selected southwestern mixed-conifer habitat types. Tree-ring samples from host trees were used to reconstruct the history of budworm outbreaks during the past several centuries, and to compare the frequency and severity of these outbreaks among the different habitat types. A study of the timing of past budworm induced tree mortality within sampled stands and radial growth effects in surviving competitor trees was also conducted.

This project was originally funded under a cooperative agreement (No. 28-C6-392) for the study of Douglas-fir host trees in 12 mixed-conifer stands. Additional funding under a contract (No. 28-K7-406) expanded the study to analysis of both Douglas-fir and white fir in 20 stands. While the entire project is to be completed by May 1989, this report is presented now in order to meet requirements of the contract. Because of the expanded sampling and analysis, all of the laboratory and interpretive work covered by both funding sources has not yet been completed. Thus, while this report provides the quantity of results called for in the contract, the overall project is still in progress and results described here must be considered a preliminary report for the entire project.

## METHODS

### SAMPLING

Stand Selection. Two general areas in northern New Mexico were selected for sampling. These were the Jemez Mountains on the Santa Fe National Forest to the west of the Rio Grande, and the Sangre de Cristo Mountains on the Carson National Forest to the east of the Rio Grande. Western spruce budworms have been a chronic defoliator pest in these areas throughout the land management tenure of the U. S. Forest Service during the twentieth century (Lessard 1975). Tree-ring studies have also demonstrated that budworm outbreaks have been a major disturbance in mixed-conifer forests of the Southern Rockies for several centuries (Swetnam in Lynch, submitted).

Forest stands were subjectively selected with the goal of obtaining samples in a range habitat types of hypothetically differing levels of susceptibility and vulnerability to budworm. The hazard rating system of Wulf and Carlson (1985) was used in a habitat type key for northern New Mexico and northern Arizona (USDA Forest Service 1987) in setting hypothesized hazard indices for different habitat types. This habitat type key was used to initially select a set of types that might be targeted for sampling.

Following reconnaissance and discussions with local Forest Service managers, watersheds on three different Ranger Districts were chosen for sampling. The watersheds included the upper Jemez River and East Fork on the Jemez Ranger District, the Rio Pueblo and La Junta on the Peñasco Ranger District, and Red River and Cabresto Creek drainages on the Questa Ranger District. These areas were selected because they are important in current management issues involving recreation, timber, and other resources. All but one of the sampled stands on the Jemez Ranger District (Fenton Lake) is within the "Integrated Forest Protection Area" which has been established by the Forest Service to study forest pests and diseases and to demonstrate management alternatives.

In addition to obtaining a range of mixed-conifer habitat types, old growth stands with no previous harvesting were sought out. These stands were expected to provide longer tree-ring records than harvested stands, and also the growth patterns of the sampled trees would not be highly influenced by past human activities.

Approximate boundaries of sampled stands were defined visually from topographic maps, aerial photos, and on-ground observations. Boundaries were generally observable as obvious shifts in age structure, species composition, or habitat type. Stand boundaries often conformed to topographic features such as ridge tops, small drainages, and canyon bottoms.

Stand and Tree Measurements. Three parallel transects were followed within each stand along the topographic contour. The transects were placed so that they would run through the approximate center on the stand, or if it was a small stand, the transects would run from near one boundary to the next. Four or five sample points were located at equally spaced intervals on each transect for a minimum of 12 sample points per stand. Transects and sample points were spaced so that approximately 5 ha was systematically covered. At each sample point variable plot techniques using a Spiegel Relascope were employed to determine stand basal area and density (basal area/ha and stems/ha) by tree species and dbh size class (Husch et al. 1982).

At each sample point the nearest Douglas-fir and white fir greater than 20.3 cm dbh (8 inches, pole size or larger) was sampled in the lower bole with an increment borer. Increment cores were obtained from at least 2 radii per tree, parallel with the contour of the slope. In addition to sampling the nearest two host trees to the sample points, five or more of the oldest appearing host trees within the stand were also cored in order to obtain the longest tree-ring record available. In some cases, white fir was relatively uncommon and could not be sampled at every point.

A set of other measurements were taken on increment cored trees and recorded on specimen cards. DBH was measured on all trees. Within each stand the height of four or five dominant or co-dominant trees was measured using a clinometer. Dwarf mistletoe ratings (Hawksworth 1977) were estimated for all cored trees in approximately half of the stands. Other recorded characteristics included presence of spike tops, crooked stems, large basal scars, and close-growing competitor trees.

Increment core collections were also obtained from ponderosa pine trees within the same watersheds as the sampled host stands. These collections were intended to provide control tree-ring chronologies for estimating the climatic effects on the host trees.

Sampling for Mortality Study. Dead host tree logs and snags were sampled within three stands in order to determine time of death and possible relationships to past budworm outbreaks. This objective was intended to provide an assessment of the potential for carrying out future studies aimed at quantifying levels of mortality caused by past budworm outbreaks.

Cross sections were taken from the logs or snags and increment cores were taken from surrounding living trees. The living trees were sampled to determine if radial growth records in these trees would reflect reduced competition due to budworm caused mortality. Distances and directions were measured between living and dead trees. Crossdating of ring-width patterns was employed (Swetnam et al. 1985) to date all annual rings and determine approximate death dates.

## LABORATORY ANALYSIS

Chronology Development. Increment core samples were mounted, dated, and measured. Separate tree-ring index chronologies were developed for Douglas-fir, white fir, and ponderosa pine. Host and non-host radial growth patterns were graphically and statistically compared (Swetnam et al. 1985, Swetnam and Lynch, submitted). Effects of climate in host (Douglas-fir and white fir) tree-ring chronologies were removed (at least partially) by subtracting non-host (pine) tree-ring chronologies collected from the same watersheds, resulting in "corrected index" chronologies (Swetnam et al. 1985). Dates of occurrence of past budworm outbreaks were identified in corrected host tree-ring chronologies as sharply reduced periods of ring-width growth. The tree-ring evidence of past outbreaks was compared with Forest Service documents and records of infestations for the period 1922 to present. Forest Service records included annual entomological reports, biological evaluations, and aerial reconnaissance maps of defoliation.

Corrected tree-ring chronologies were plotted individually and together with chronologies from other sites within the same watershed. These plots were used to evaluate regional patterns of past budworm outbreaks.

Maximum growth reduction values during outbreaks occurring in the twentieth century were complied for all of the analyzed chronologies. Growth reductions were computed as the percent decrease from the expected growth levels, which in tree-ring index chronologies is a value of 1.0. Thus, the percent maximum growth reduction was computed as: 1.0 - (the lowest index value for the outbreak period) X 100. The maximum growth reduction years were compared among the different species and sites and ranked by level of severity; higher maximum growth reduction estimates received higher ranks. Earlier outbreaks occurring in the 19th, 18th, and 17th century have also been tentatively identified, but will not be extensively considered in this report.

Variable Plot Data. Variable plot measurements were entered in a microcomputer database (dBase III). These data were reduced to a set of tables listing the distribution of stand density by species and size class. Illustrations of these data were also prepared. These basic stand description data will be used in later analysis of the relation of budworm outbreak history, stand structure and species composition.

# RESULTS

## SPECIES AND DENSITY MEASUREMENTS

Locations and physiographic characteristics of the 20 sampled stands are listed in Table 1. The stands include a variety of habitat types, elevations, and general topographic settings. The habitat types include three different series: *Abies concolor* (ABCO), *Abies lasiocarpa* (ABLA) and *Picea pungens* (PIPU). The types range from hypothetically high budworm susceptibility/vulnerability ratings (ABCO/ACGL), to moderate (ABCO/QUGA, ABCO/ARUV), to low (ABCO/VAMY) (USDA Forest Service 1987). Elevations range from 2,450 to 3,050 m. Most stands are on north or south aspects with slopes of greater than 10 percent.

Figures 1 through 4 illustrate the distribution of basal area and stems per ha within the 20 sampled stands sorted by the three primary host species and non-host species. Appendix B1 and B2 contain listings for individual species and dbh size classes. It is clear that a variety of stand structures and species composition are represented. Old growth stands typically show higher basal area per ha values in the larger diameter classes. However, in some cases large numbers of smaller trees in old growth stands results in skewed to-the-left distributions. Examples of old growth stands include Peralta High, Frijoles Canyon, Alamitos, and Rito Claro. Younger stands with almost all trees in the smaller size classes include Red River, Los Griegos, and Fenton Lake. These latter three stands appear to have established in the late 1800s after stand replacing disturbances (as evidenced by the earliest ring dates on increment cored trees).

Table 1. Location and description of sampled stands.

| Site Name | Township(N), Range(E),Sec. | Habitat Type | Elev.(m) | Slope % | Aspect° |
|---|---|---|---|---|---|
| *Jemez Ranger District:* | | | | | |
| Peralta West | 19,4,3 | ABCO/ACGL | 2,720 | 20-50 | 325-30 |
| Peralta High | 18,4,NE¼ 2 | ABCO/VAMY | 2,790 | 30-60 | 10 |
| West Vallecitos | 19,3,SW¼ 10 | ABCO/QUGA | 2,510 | 40-60 | 30 |
| Frijoles Canyon | 19,5,SW¼ 27 | ABCO/QUGA | 2,730 | 10-20 | 230 |
| Los Griegos High | 19,4,NE¼ 18 | ABCO/ACGL | 2,930 | 50-60 | 345 |
| Los Griegos Low | 18,4,NE¼ 7 | ABCO/ACGL | 2,870 | 10-50 | 345 |
| Fenton Lake | 20,2,13 | ABCO/ACGL | 2,500 | 40-50 | 340-360 |
| East Fork | 18,3,NE¼ 6 | PIPU/LIBO | 2,580 | 40-50 | 340-360 |
| Lower East Fork | 18,3,NW¼ 1 | PIPU/EREX | 2,450 | 45-50 | 350-10 |
| Barley Ridge | 20,2,10 | ABCO/QUGA | 2,610 | flat | flat |
| *Questa Ranger District:* | | | | | |
| Bonita Canyon | 29,14,NE¼ 20 | ABLA/VAMY | 2,780 | 10-43 | 300-360 |
| Singing River | 29,13,28 | ABCO/SYOR | 2,710 | 50-70 | 300-40 |
| Rito Claro | 29,14,NE¼ 10 | ABCO/ARUV | 2,870 | 10-30 | 110-190 |
| Fawn Lakes | 29,14,33 | ABCO/ARUV | 2,850 | 20-80 | 10-20 |
| Red River | 29,14,SW¼ 36 | ABCO/ARUV | 2,770 | 40-65 | 350-50 |
| *Peñasco Ranger District:* | | | | | |
| Policarpio Canyon | 22,14,NW¼ 16 | PIPU/EREX | 2,758 | 50-85 | 140-190 |
| Flechado Canyon | 23,13,SW¼ 2 | ABCO/VAMY | 2,740 | 10-30 | 100-150 |
| Alamitos | 22,14,SW¼ 5 | ABCO/VAMY | 3,050 | 1-15 | 320-40 |
| Alamitos West | 22,14,SE¼ 6 | ABLA/VAMY | 3,050 | 1-15 | 45-80 |
| La Junta | 22,14,NW¼ 19 | ABCO/QUGA | 2,730 | 30-60 | 120-190 |

Figure 1. Distribution of basal area sorted by host and non-host tree species in sampled stands on the Jemez Ranger District, Santa Fe National Forest.

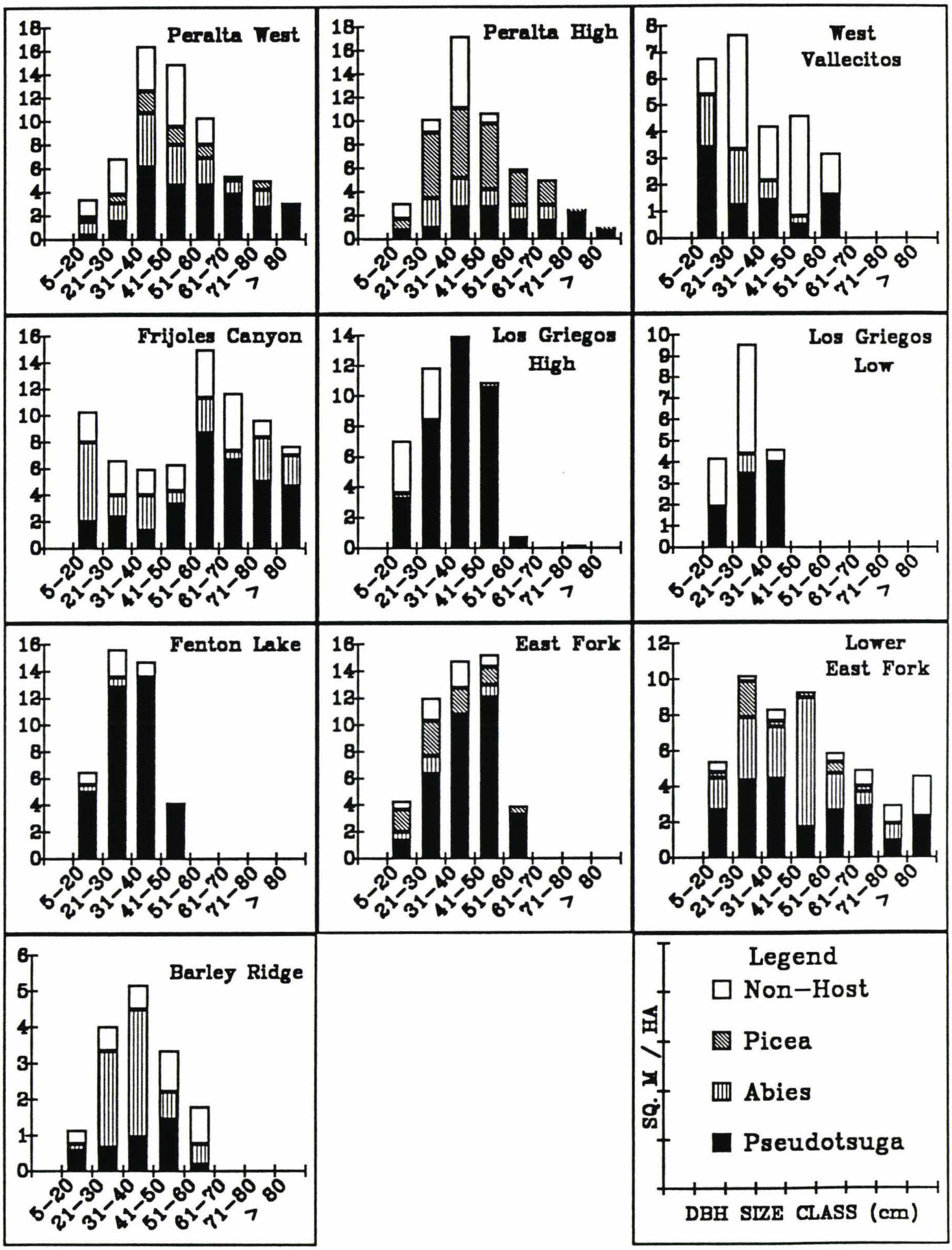


Figure 2. Distribution of basal area sorted by host and non-host tree species in sampled stands on the Questa and Peñasco Ranger Districts, Carson National Forest.

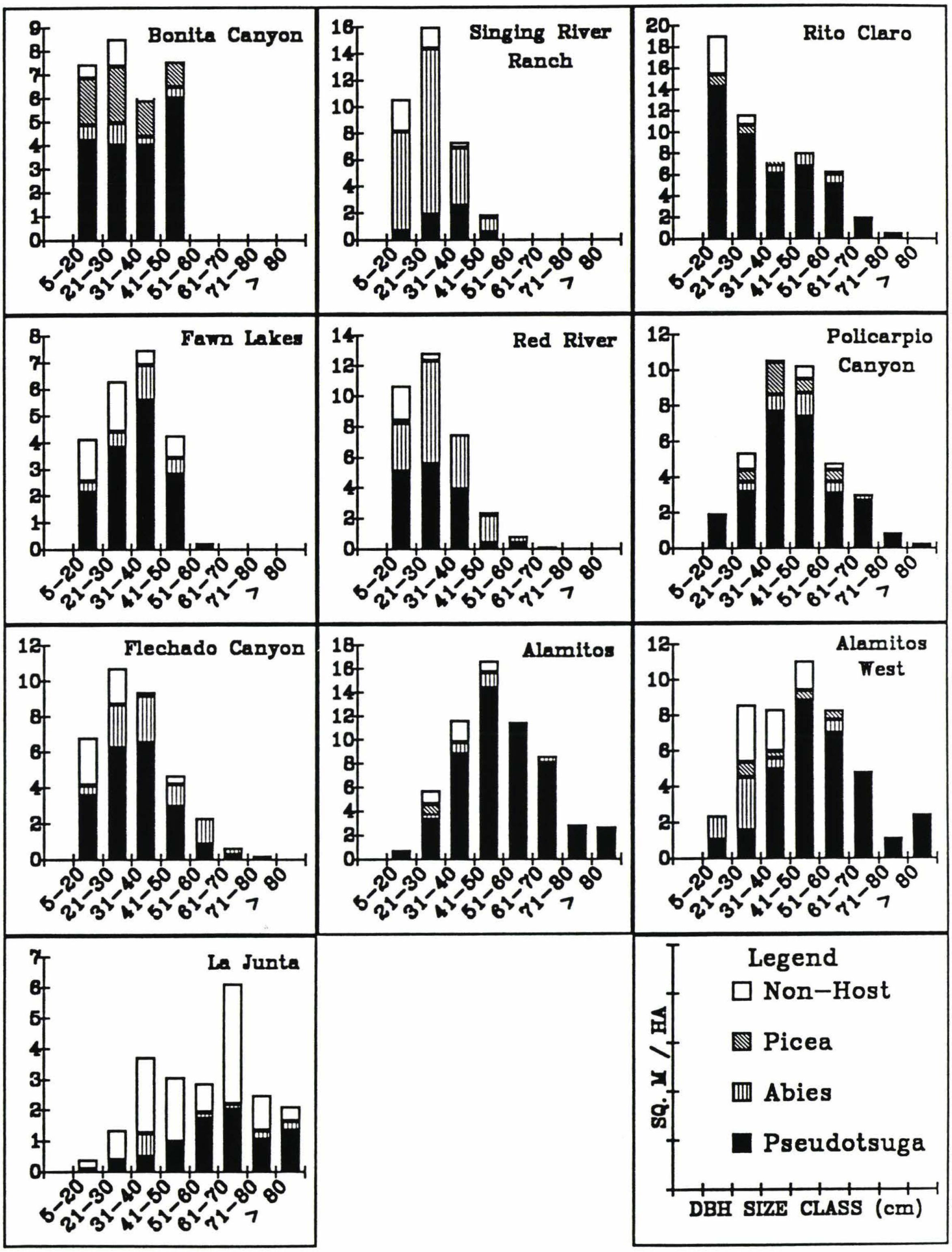


Figure 3. Distribution of stems per hectare sorted by host and non-host species in sampled stands on the Jemez Ranger District, Santa Fe National Forest.

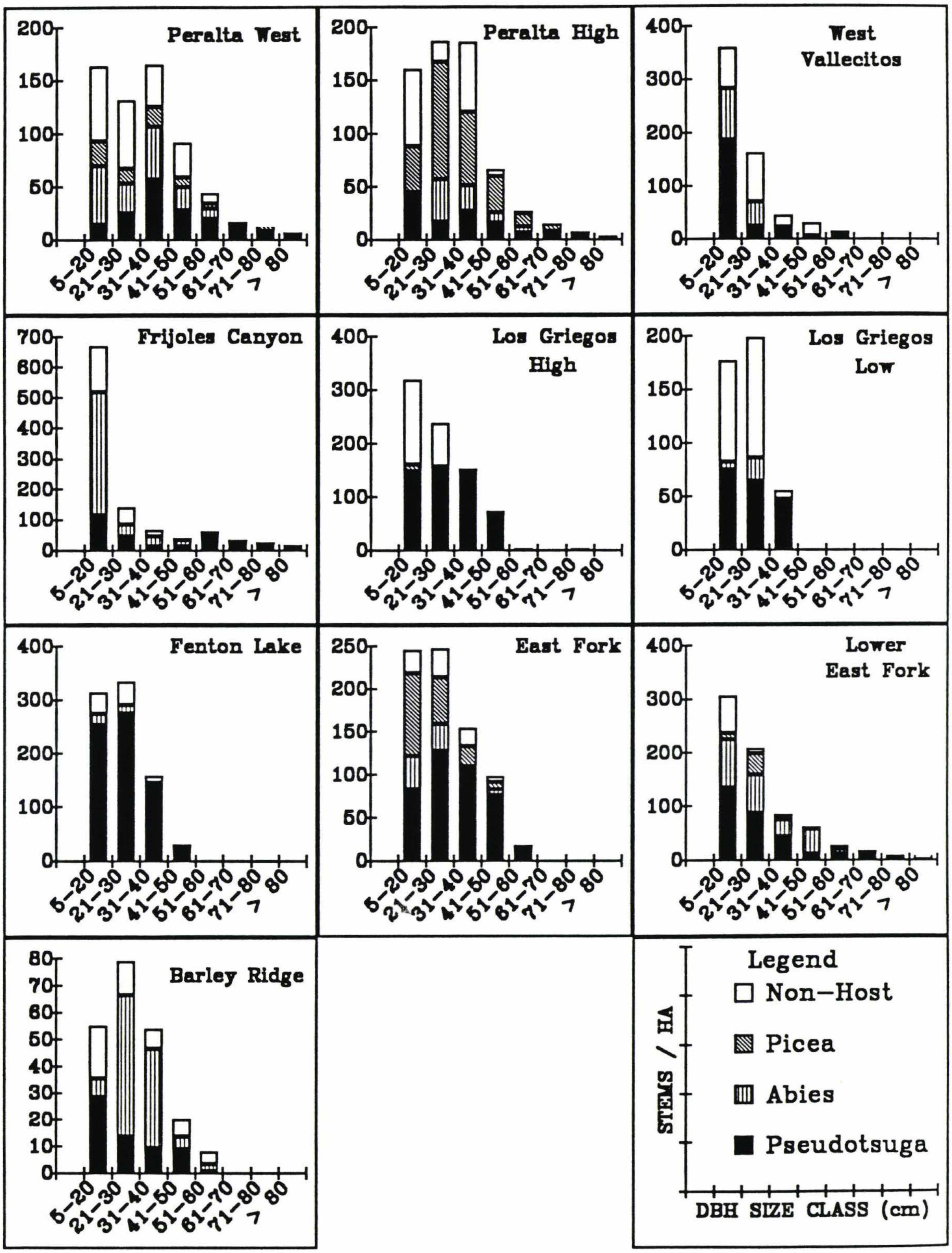
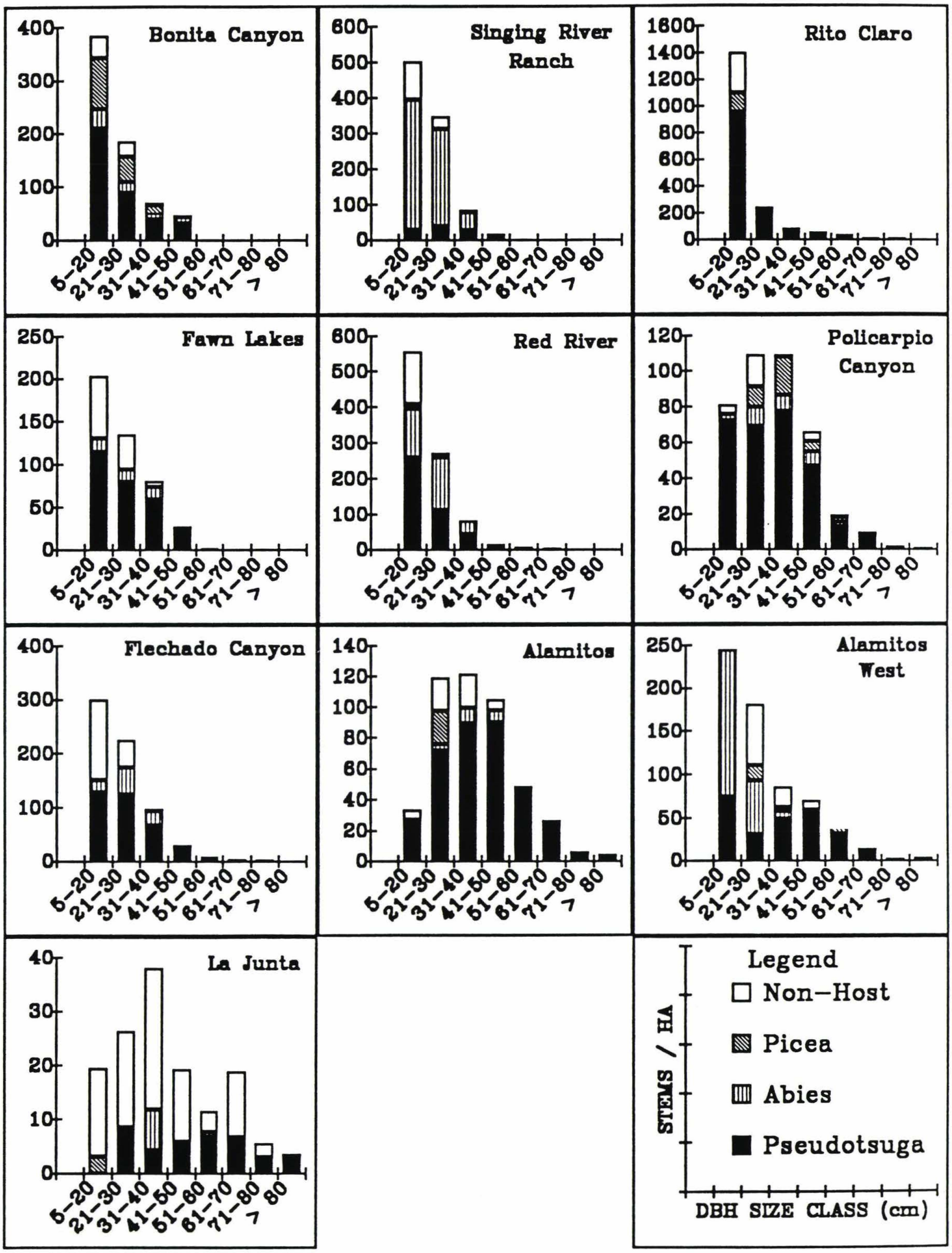


Figure 4. Distribution of stems per hectare sorted host and non-host tree species in sampled stands on the Questa and Peñasco Ranger Districts, Carson National Forest.



## TREE-RING CHRONOLOGIES

Tables 2 and 3 list the number of trees that were sampled by increment coring and the number that have been analyzed to date. At this time approximately half the total number of the sampled stands and trees have been processed through the chronology development and correction stages. Table 4 lists descriptive statistics for all of the completed ponderosa pine (PIPO) and uncorrected Douglas-fir (PSME) and white fir (ABCO) chronologies.

In general, the strategy of utilizing non-host tree-ring chronologies to correct for climatic variations in the host chronologies was quite successful. Correlations of the host and non-host chronologies across their entire common periods were between 0.4 and 0.8 (Pearson's correlation coefficient). "Moving correlation coefficients" (Swetnam 1987) for 15-year periods usually ranged from 0.7 to 0.9 between outbreaks and dropped to as low as 0.1 or negative values during identified outbreak periods. Both standard index chronologies and pre-whitened index chronologies (Biondi and Swetnam 1988) were analyzed in the correlation studies. Year-to-year ring index variance in the host chronologies was reduced approximately 30 to 60 percent by the correction procedure.

Figures 5, 6, and 7 show examples of the 20th-century portions of the corrected Douglas-fir and white fir chronologies. In general, the period after about 1800 has sufficient sample depth among all the chronologies to identify past outbreaks with some confidence. Figures 8, 9 and 10 show low pass filtered post-1800 portions of Douglas-fir and white fir chronologies grouped by Ranger District (i.e., major watersheds). Appendix A is a list of all corrected index values for Douglas-fir and white fir series.

Table 2. Number of host trees sampled and currently analyzed. 3-Letter codes refer to labels in illustrations and Appendix A.

| | | PSME | | ABCO | |
|---|---|---|---|---|---|
| Site Name | 3-Letter Code | Sampled | Analyzed | Sampled | Analyzed |
| Peralta West | PER | 17 | 17 | 14 | 11 |
| Peralta High | PEH | 17 | - | 12 | - |
| West Vallecitos | WVA | 18 | - | 18 | - |
| Frijoles Canyon | FRC | 17 | 12 | 20 | 19 |
| Los Griegos High | LGR | 17 | 16 | 9 | 8 |
| Los Griegos Low | LOG | 18 | - | 13 | - |
| Fenton Lake | FNL | 18 | 17 | 13 | 12 |
| East Fork | EFK | 18 | - | 19 | - |
| Lower East Fork | LEF | 17 | - | 14 | - |
| Barley Ridge | BAR | 15 | - | 16 | - |
| Bonita Canyon | BON | 19 | 19 | 18* | 15 |
| Singing River Ranch | SRR | 16 | 16 | 17 | 17 |
| Rito Claro | RTC | 19 | 19 | 20 | 18 |
| Fawn Lakes | FWN | 17 | - | 18 | - |
| Red River | RED | 20 | - | 17 | - |
| Policarpio Canyon | POL | 17 | 17 | 15 | 15 |
| Flechado Canyon | FLE | 16 | - | 15 | - |
| Alamitos | ALA | 21 | 20 | 16 | 15 |
| Alamitos West | ALW | 14 | - | 11** | - |
| La Junta | LAJ | 16 | 15 | 12 | 12 |
| | Totals: | 348 | 168 | 307 | 142 |

---

* Includes 10 ABLA and 8 ABCO.

** Includes 3 ABLA and 8 ABCO.

Table 3. Number of ponderosa pine trees sampled and analyzed for this report.

| Site Name | Sampled | Analyzed |
|---|---|---|
| *Jemez Ranger District*: | | |
| Abouselman Spring | 17 | - |
| Fenton Lake | 17 | 13 |
| Cat Mesa | 19 | 13 |
| Baca Pine | 21 | 19 |
| *Questa Ranger District*: | | |
| Elephant Rock | 18 | - |
| Cabresto Pine | 20 | - |
| *Peñasco Ranger District*: | | |
| Rio Pueblo | 16 | 16 |
| Mouth of La Junta | 11 | 10 |
| Totals: | 139 | 71 |

Table 4. Descriptive statistics for tree-ring chronologies.

| Chron. ID | Species | Total Period | 90% Var.[1] Agrmt. | Mean[2] Sens. | S/N Ratio | % Absent Rings | Partial Autocor. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | 2 | 3 |
| PEW | PSME | 1737-1986 | 1808(8) | .179 | 10.8 | .475 | .717 | .159 | .043 |
| | ABCO | 1839-1986 | 1877(5) | .194 | 12.7 | .816 | .763 | .158 | -.030 |
| FRC | PSME | 1702-1987 | 1814(4) | .289 | 18.9 | .028 | .443 | .130 | .037 |
| | ABCO | 1808-1987 | 1867(4) | .242 | 17.7 | .082 | .573 | .119 | .108 |
| LGR | PSME | 1705-1986 | 1885(6) | .237 | 15.7 | .124 | .419 | .098 | .120 |
| | ABCO | 1881-1986 | 1893(4) | .216 | 5.9 | .000 | .501 | .101 | .053 |
| FNL | PSME | 1831-1986 | 1876(4) | .320 | 32.5 | .222 | .439 | .030 | .007 |
| | ABCO | 1850-1986 | 1881(4) | .328 | 23.8 | .000 | .349 | .149 | .118 |
| BON | PSME | 1340-1986 | 1600(7) | .231 | 9.9 | .058 | .417 | .114 | .035 |
| | ABCO | 1681-1986 | 1830(7) | .277 | 7.5 | .103 | .675 | .363 | .143 |
| SRR | PSME | 1760-1986 | 1760(4) | .422 | 25.6 | 2.002 | .087 | .008 | .143 |
| | ABCO | 1758-1986 | 1767(5) | .358 | 18.4 | .415 | .183 | .023 | .154 |
| RTC | PSME | 1283-1987 | 1701(6) | .381 | 19.3 | .453 | .188 | .150 | .094 |
| | ABCO | 1718-1987 | 1852(7) | .296 | 13.4 | .159 | .337 | .153 | .065 |
| POL | PSME | 1656-1986 | 1732(3) | .303 | 13.9 | .175 | .570 | .225 | .085 |
| | ABCO | 1840-1986 | 1897(5) | .284 | 9.2 | .257 | .527 | .203 | .108 |
| ALA | PSME | 1602-1986 | 1667(7) | .281 | 15.1 | .315 | .398 | .143 | .058 |
| | ABCO | 1630-1986 | 1750(5) | .310 | 16.1 | .343 | .458 | .239 | .076 |
| LAJ | PSME | 1685-1986 | 1817(4) | .320 | 18.5 | .212 | .558 | .158 | .114 |
| | ABCO | 1818-1986 | 1885(4) | .236 | 11.1 | .405 | .447 | .051 | .116 |
| BAC | PIPO | 1653-1987 | 1700(6) | .347 | 11.1 | 1.127 | .287 | .152 | .058 |
| CAT | PIPO | 1572-1986 | 1633(5) | .350 | 8.8 | 1.501 | .363 | .200 | .095 |
| FEN | PIPO | 1532-1986 | 1606(5) | .363 | 7.7 | 1.593 | .406 | .139 | .069 |
| RIO | PIPO | 1555-1986 | 1640(5) | .380 | 19.9 | 1.299 | .289 | .129 | .098 |
| MOJ | PIPO | 1690-1986 | 1791(5) | .343 | 9.2 | .714 | .421 | .145 | .014 |

---

[1] 90% variance agreement refers to the theoretical sample size of trees that would have to be sampled, one core per tree, to develop a chronology whose variance would be in 90% agreement with the actual chronology (Wigley et al. 1984). The year in the actual chronology where this sample size is reached is listed with the sample size (number of trees) in parenthesis.

[2] Mean sensitivity and signal-to-noise ratio are measures of year-to-year variance and inter-tree correlation respectively (Fritts 1976).

Figure 5. Post-1900 Douglas-fir (solid line) and white fir (dotted line) corrected chronologies from the Jemez Ranger District.

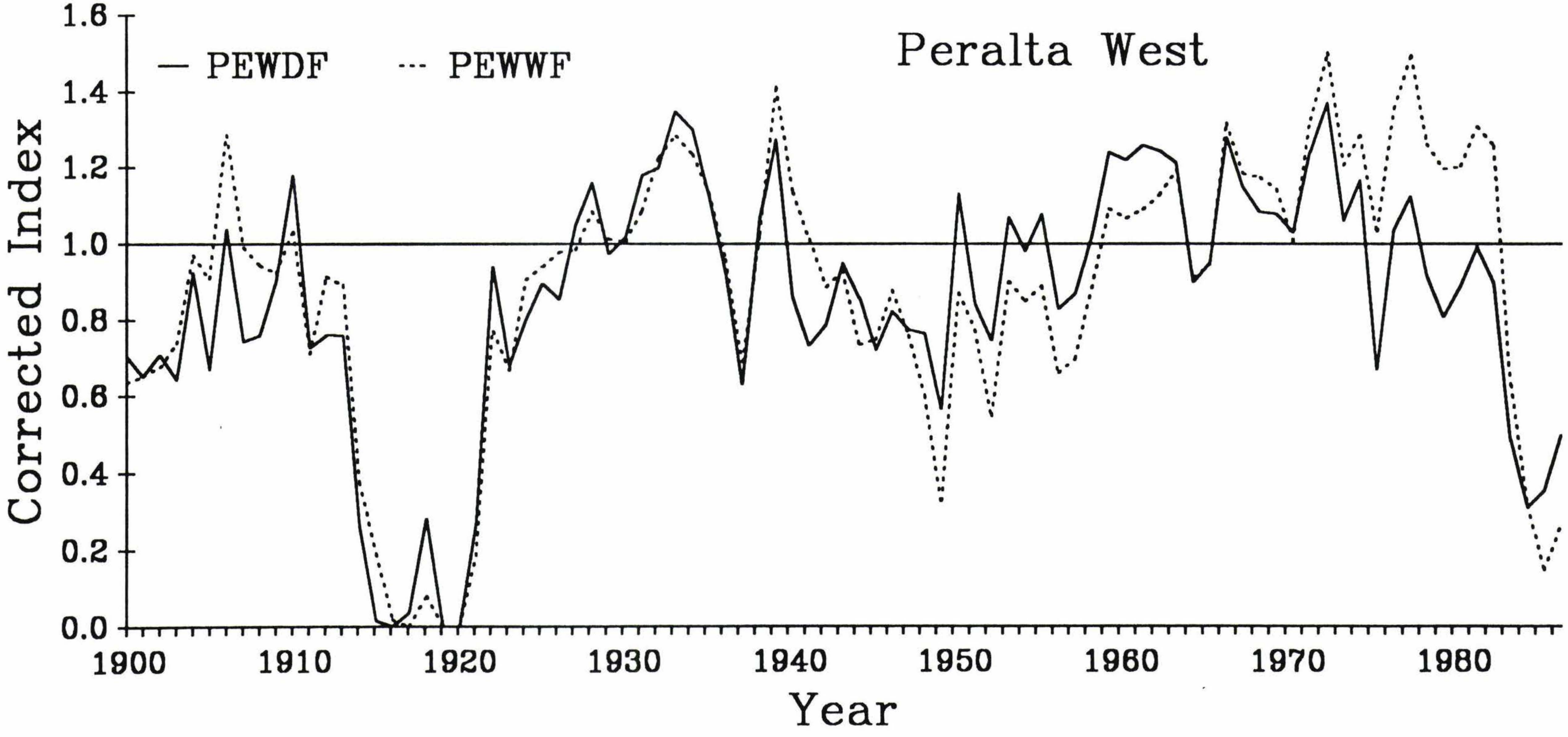


Figure 6. Post-1900 Douglas-fir (solid line) and white fir (dotted line) corrected chronologies from the Jemez Ranger District.

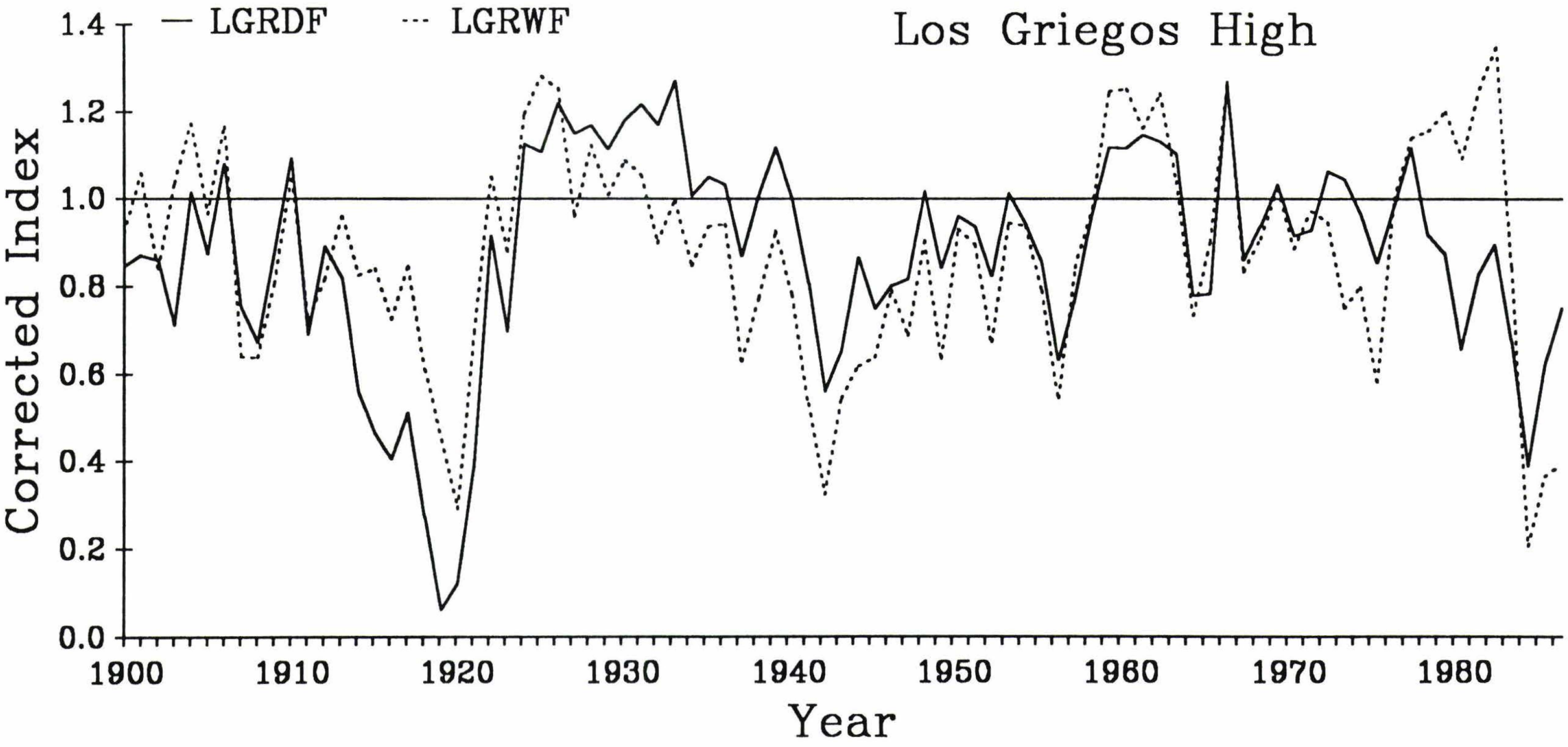


Figure 7. Post-1900 Douglas-fir (solid line) and white fir (dotted line) corrected chronologies from the Jemez Ranger District.

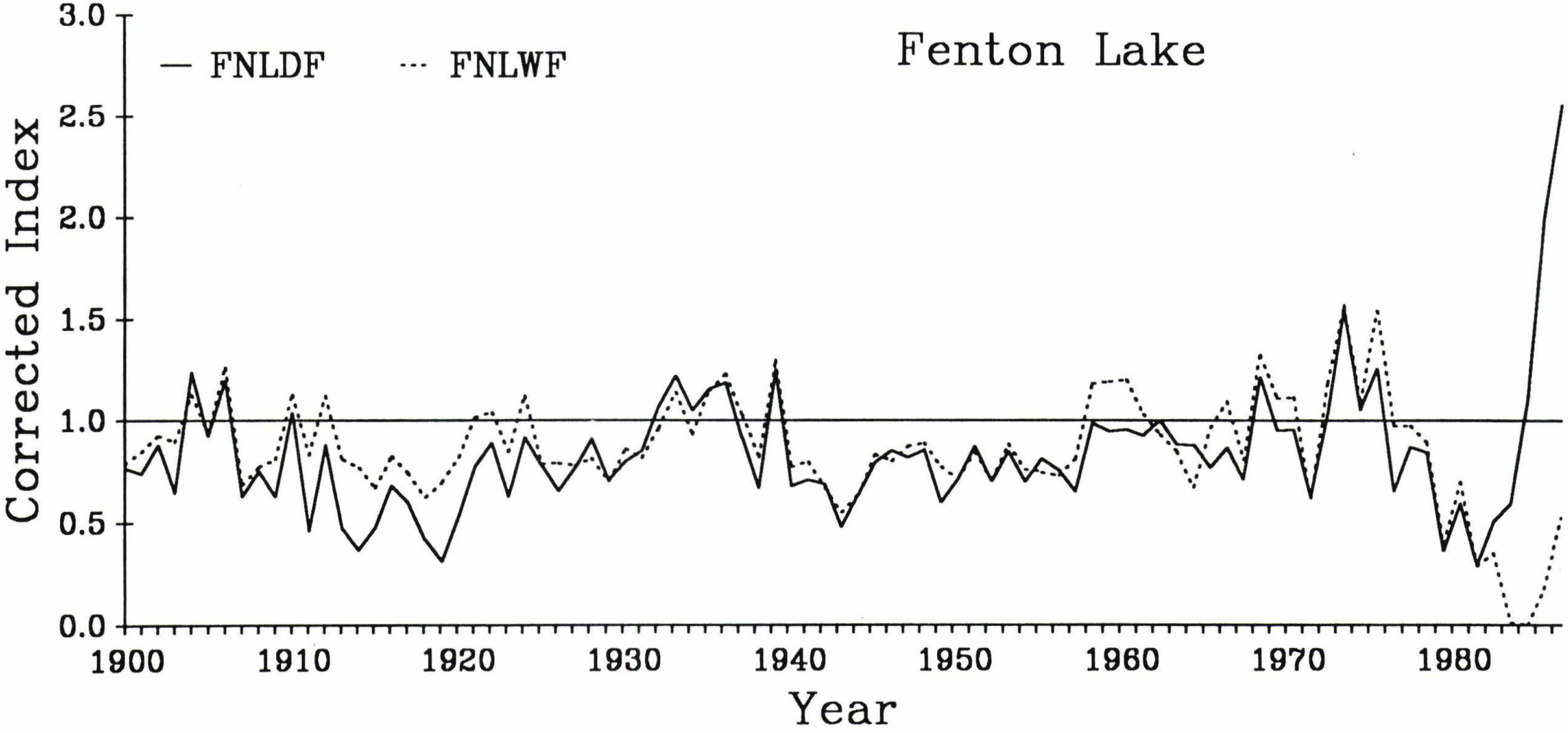


Figure 8. Low-pass filtered Douglas-fir (upper plot) and white fir (lower plot) chronologies from the Jemez Ranger District. Approximate timing of major outbreaks are indicated with vertical dotted lines. Note that these time series were smoothed with a thirteen-weight digital filter (Fritts 1976) to de-emphasize the year-to-year growth changes in the chronologies and to emphasize the longer-term growth trends. The filtered series end six years earlier than the unfiltered series because the algorithm utilizes weighted values of the preceding six years (t-1...t-6) and subsequent six years (t+1...t+6) to compute the filtered value for each year (t).

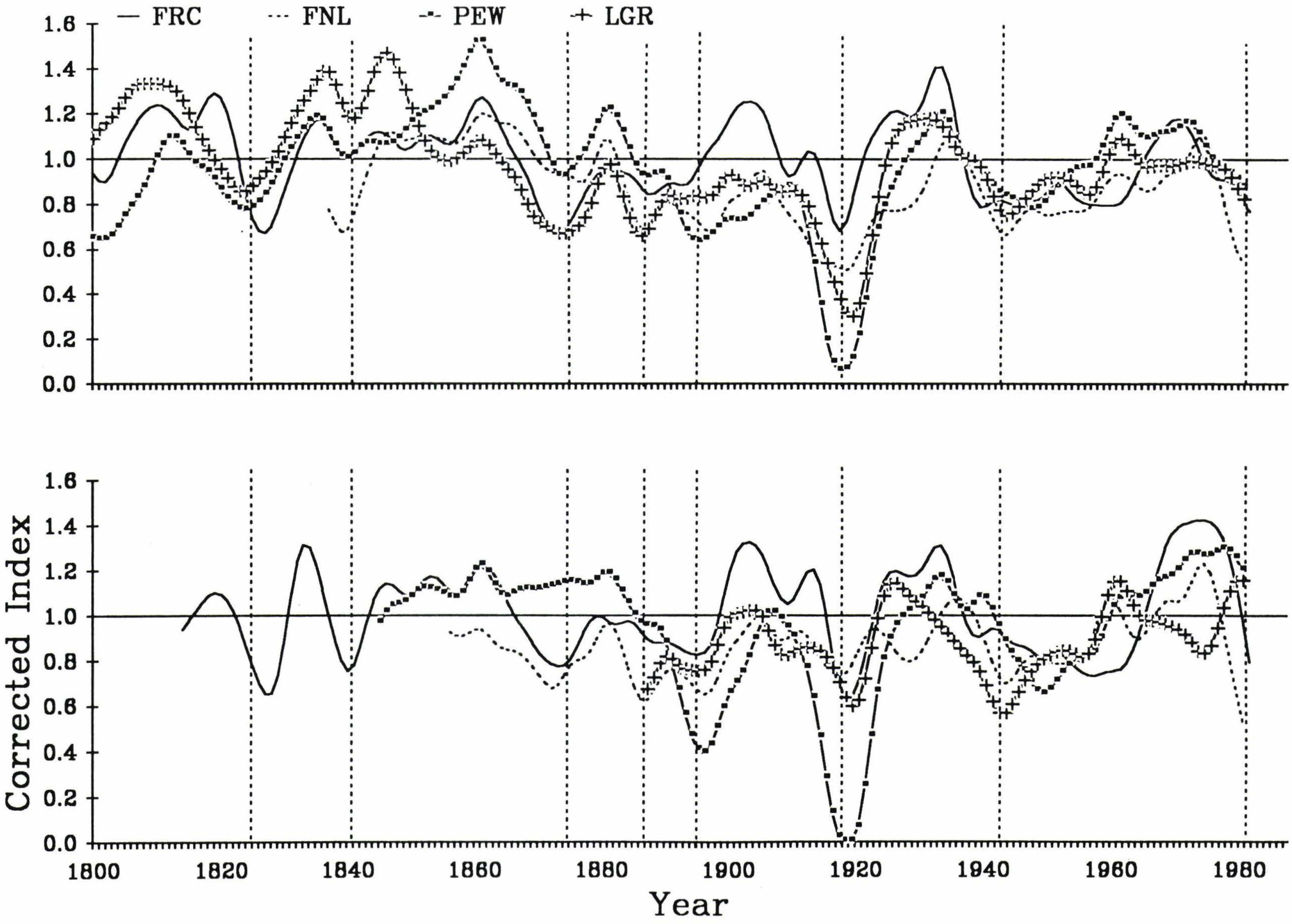


Figure 9. Low-pass filtered Douglas-fir (upper plot) and white fir (lower plot) chronologies from the Questa Ranger District. Approximate timing of major outbreaks are indicated with vertical dotted lines.

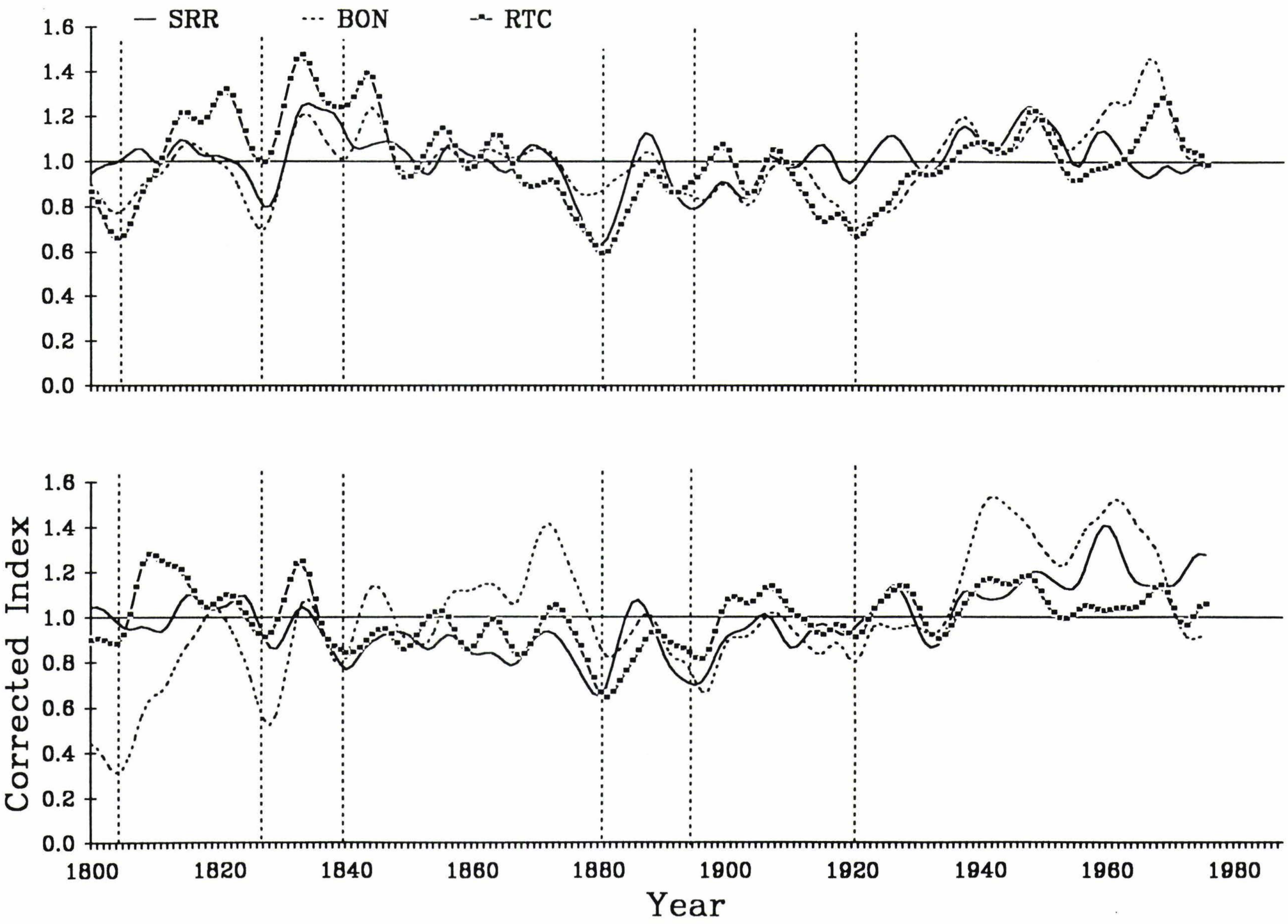
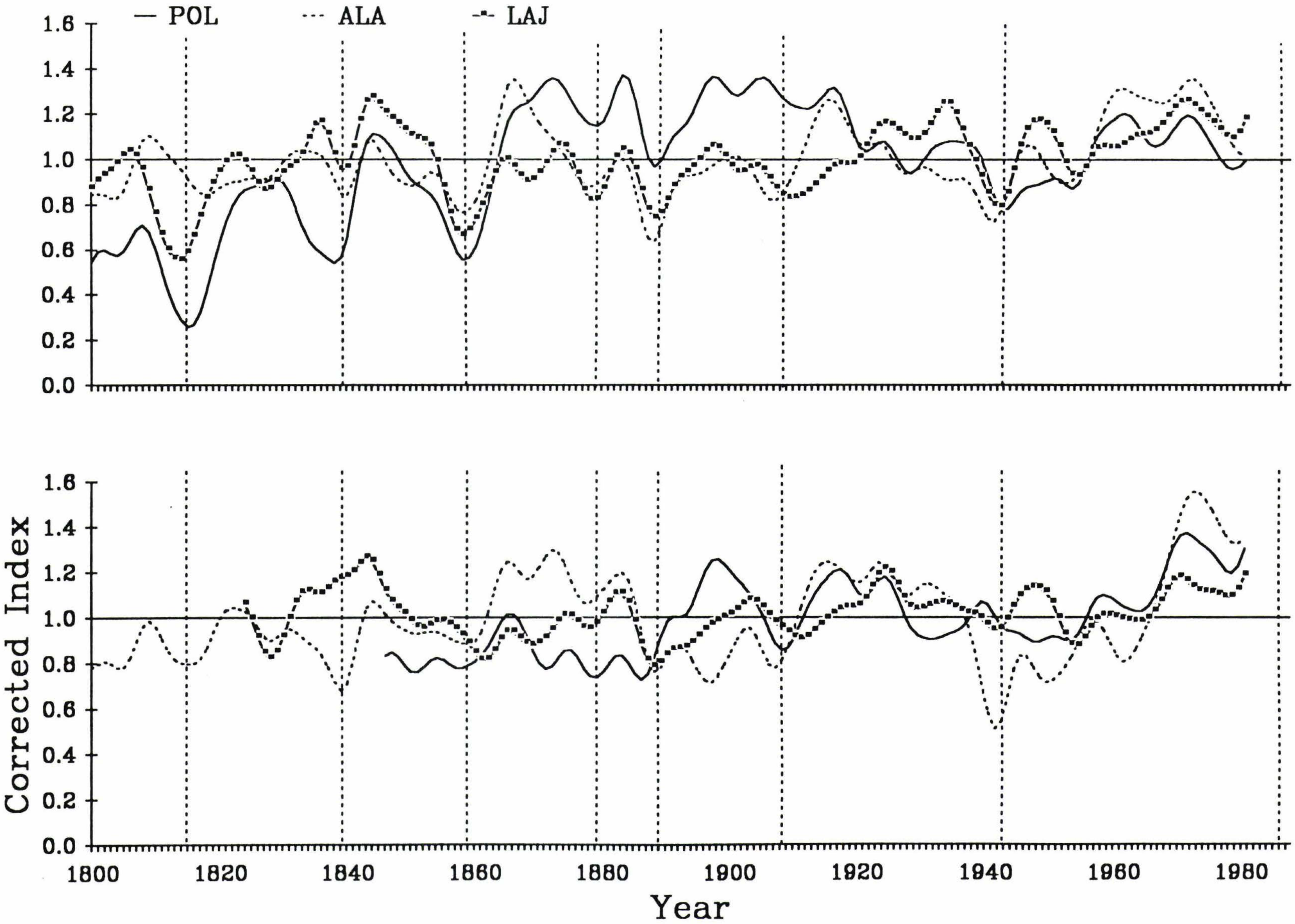


Figure 10. Low-pass filtered Douglas-fir (upper plot) and white fir (lower plot) chronologies from the Peñasco District. Approximate timing of major outbreaks are indicated with vertical dotted lines.



Three budworm outbreak periods are easily observable in most of the chronologies. The first period extended from approximately 1910 to 1925. This outbreak was particularly severe in the Jemez Mountains (figs. 5 to 8). Previous tree-ring studies (Swetnam and Lynch, submitted) detected this outbreak in only one other stand on the western side of the Rio Grande (Burned Mountain, Tres Piedras Ranger District).

The next outbreak covers the 1940s up to the early 1960s. In some areas this almost appears as two outbreaks separated by a recovery phase. In other sites only the early or latter portion of the period shows substantial growth reduction. This pattern coincides well with the Forest Service documentary record. For example, a severe outbreak was recorded on portions of the Carson and Santa Fe National Forests in the early and mid-1940s. Budworm activity then declined in the late 1940s. Reports of heavy defoliation appear again in the records in the early and mid-1950s. Some areas also sustained defoliation into the early 1960s.

The chronologies from the Questa Ranger District do not show definite signs of budworm induced growth reduction during the 1940s-1960s outbreak (fig 9). It seems that this outbreak may not have spread to the Cabresto or Red River watersheds, or at least not to the sampled stands.

The most recent outbreak began in the late 1970s in most of the sampled stands. Again, the timing of reduced growth (and apparent recovery in some stands) corresponds remarkably well with historic records. For example reduced growth is evident at the Los Griegos High stand (fig. 6) in the late 1970s, especially in the white fir. Budworm was observed in this area as early as 1976. An increase in growth is observed in this stand just before 1980, then growth declined again as the outbreak resurged. This pattern matches a record of defoliation observations that was compiled for an area including the analyzed stands (Telfer 1984).

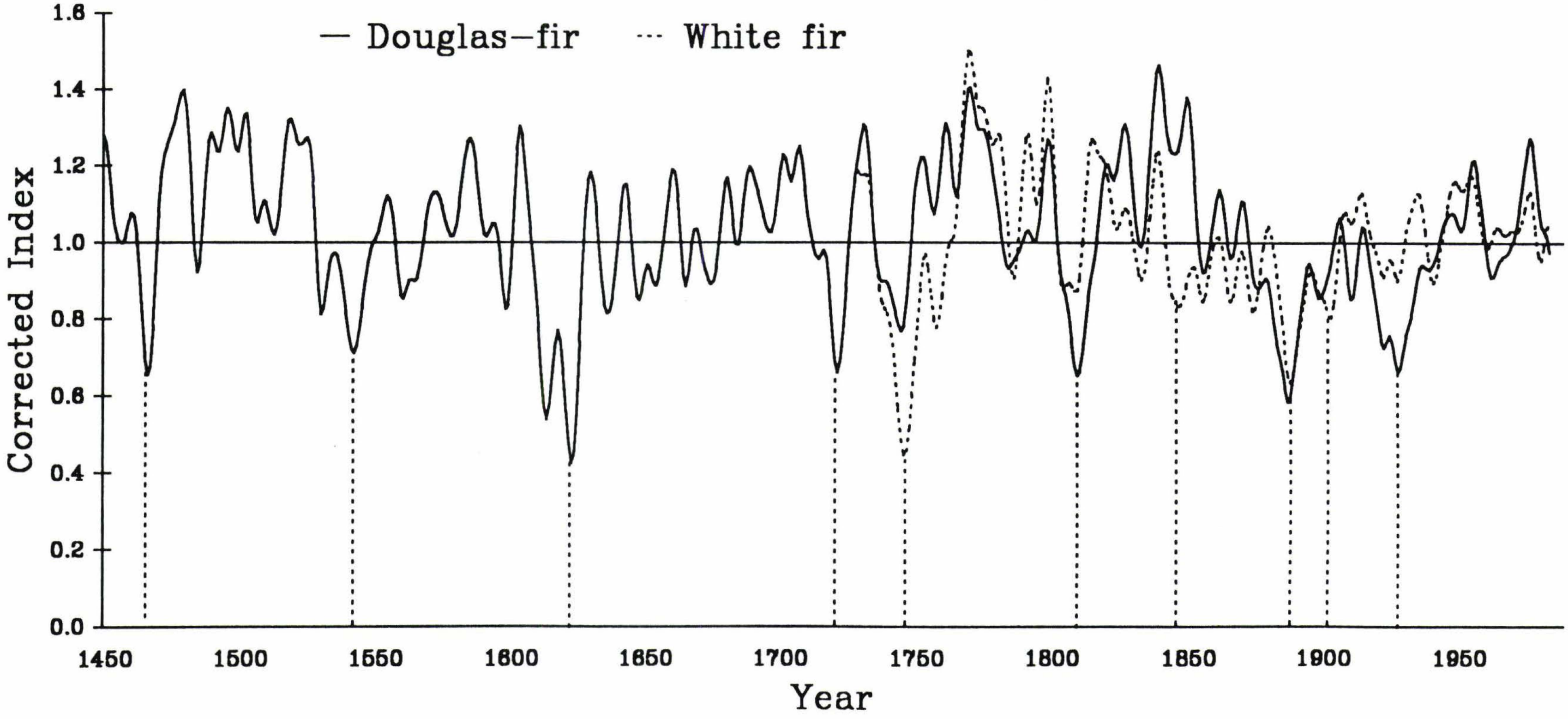
The Fenton Lake growth record is also quite interesting. A very large growth release is evident in the surviving Douglas-fir at this site after 1982. This stand suffered very extensive mortality (at least 70% in some areas) and it appears that the surviving trees are now benefiting from the reduced competition (fig. 7). Many of the white fir appeared to be dying when they were cored. The mean growth of these trees shows that at least some are beginning to recover.

The recent outbreak has just begun in the stands in the Rio Pueblo and La Junta watersheds on the Peñasco Ranger District. Aerial defoliation maps show this outbreak just reaching the La Junta, Policarpio and Alamitos stands in 1985 or 1986. As expected, these chronologies show sharp growth reduction in the last sampled year of 1986.

Particularly notable is the very long period of record contained in some collections. For example, four Douglas-fir trees exceeding 400 years of age were sampled at the Rito Claro site in the Cabresto watershed, and another sampled tree was over 700 years old (pith date 1283)! These are among the oldest living trees we are aware of in northern New Mexico. Considering that most of the samples from this site were selected as nearest neighbors to sampling points it is likely that additional extreme old-age tres could be found and sampled at this site. This may be a worthwhile objective for further work aimed at obtaining exceptionally long budworm outbreak chronologies.

Figure 11 shows Douglas-fir and white fir chronologies from the Rito Claro stand extending back to 1450. The most recent outbreak is recorded in the unfiltered series as reduced growth beginning about 1976 (Appendix A).

Figure 11. Low-pass filtered Douglas-fir and white fir chronologies from the Rito Claro stand, Questa Ranger District. Approximate timing of major outbreaks are indicated with vertical dotted lines.



## TWENTIETH CENTURY SEVERITY AND RANKING

Maximum growth reductions during three major budworm outbreak periods were computed for the 20th century periods of all chronologies. Table 5 lists the percent maximum growth reduction values for all chronologies and outbreak periods. Mean growth reductions for stands within Ranger Districts are also listed.

The rankings of severity (measured by maximum growth reduction) show that the Jemez stands tended to sustain the highest levels of growth reduction among the three sampled areas. The Questa and Peñasco areas have equal mean growth reductions, but as mentioned earlier, the Questa stands appear to have been missed by the 1940-1960 outbreak.

In general the Ranger District grouping of chronologies seems to show better temporal correspondence (or frequency) of outbreaks (figs 8, 9, 10) than sorting by habitat type. Consider a general habitat type grouping for the 1910-1925 outbreak period:

| Group<br>Habitat Type | No. of Stands Analyzed | Hypothesized Susceptibility | Mean Max. Growth Reduction(%) Hab. Type | Mean Max. Growth Reduction(%) Group |
|---|---|---|---|---|
| 1. Cold, subalpine | | | | 45.2 |
| ABCO/VAMY | 2 | low | 47.3 | |
| PIEN/EREX | 1 | low | 41.0 | |
| 2. Dry white fir | | | | 46.8 |
| ABCO/QUGA | 2 | moderate | 45.8 | |
| ABCO/SYOR | 1 | moderate | 49.0 | |
| ABCO/ARUV | 1 | moderate | 46.5 | |
| 3. Mesic white fir | | | | 78.7 |
| ABCO/ACGL | 3 | high | 78.7 | |

Table 5. Maximum growth reduction expressed as a percent of the expected growth level during three 20th century outbreaks. Growth reductions were ranked within each outbreak period for all twenty host chronologies. Increasing ranks correspond to relative increasing maximum growth reduction.

| | | Outbreak Period[1] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1905 - 1925 | | | 1940 - 1960 | | | 1975 - 1986 | | | Mean Rank | |
| Site Name<br>Habitat Type | Species | Year | % | Rank | Year | % | Rank | Year | % | Rank | Site | District |
| Jemez Ranger District: | | | | | | | | | | | | 13.6 |
| Peralta West | PSME | 1919 | 100 | 20.0 | 1949 | 43 | 8.5 | 1984 | 69 | 7.5 | 14.3 | |
| ABCO/ACGL | ABCO | 1919 | 100 | 19.0 | 1949 | 67 | 18.0 | 1985 | 85 | 12.0 | 18.3 | |
| Frijoles Canyon | PSME | 1918 | 61 | 15.0 | 1954 | 61 | 16.0 | 1981 | 46 | 2.5 | 12.6 | |
| ABCO/QUGA | ABCO | 1918 | 56 | 12.0 | 1954 | 60 | 15.0 | 1981 | 46 | 11.0 | 11.3 | |
| Los Griegos High | PSME | 1919 | 94 | 18.0 | 1942 | 44 | 10.0 | 1984 | 61 | 6.0 | 13.7 | |
| ABCO/ACGL | ABCO | 1920 | 71 | 17.0 | 1942 | 68 | 19.0 | 1984 | 79 | 10.0 | 17.7 | |
| Fenton Lake | PSME | 1919 | 69 | 16.0 | 1943 | 52 | 12.5 | 1981 | 71 | 9.0 | 14.8 | |
| ABCO/ACGL | ABCO | 1918 | 38 | 4.0 | 1943 | 45 | 11.0 | 1984 | 100 | 14.0 | 11.7 | |
| Mean: | | | 74 | 15.1 | | 55 | 13.8 | | 70 | 9.0 | | |
| Questa Ranger District: | | | | | | | | | | | | 7.9 |
| Bonita Canyon | PSME | 1920 | 58 | 13.5 | - | - | 3.5 | 1981 | 46 | 2.5 | 11.9 | |
| ABLA/VAMY | ABCO | 1920 | 54 | 10.5 | - | - | 3.5 | 1981 | 69 | 7.5 | 9.5 | |
| Singing River Ranch | PSME | 1918 | 54 | 10.5 | - | - | 3.5 | 1981 | 87 | 13.0 | 11.0 | |
| ABCO/SYOR | ABCO | 1911 | 39 | 5.0 | - | - | 3.5 | 1981 | 56 | 5.0 | 6.5 | |
| Rito Claro | PSME | 1920 | 58 | 13.5 | - | - | 3.5 | 1981 | 48 | 4.0 | 8.7 | |
| ABCO/ARUV | ABCO | 1905 | 40 | 6.0 | - | - | 3.5 | 1979 | 21 | 1.0 | 4.2 | |
| Mean: | | | 51 | 9.8 | | | 3.5 | | 55 | 5.5 | | |
| Peñasco Ranger District: | | | | | | | | | | | | 7.9 |
| Policarpio Canyon | PSME | 1921 | 31 | 2.0 | 1954 | 40 | 7.0 | 1986 | 57 | 12.0 | 7.0 | |
| PIPU/EREX | ABCO | 1908 | 51 | 9.0 | 1954 | 53 | 14.0 | - | - | 1.5 | 8.2 | |
| Alamitos | PSME | 1908 | 42 | 7.0 | 1941 | 63 | 17.0 | 1986 | 27 | 4.5 | 9.5 | |
| ABCO/VAMY | ABCO | 1908 | 35 | 3.0 | 1941 | 100 | 20.0 | 1986 | 49 | 10.0 | 11.0 | |
| La Junta | PSME | 1908 | 44 | 8.0 | 1941 | 52 | 12.5 | 1986 | 27 | 4.5 | 8.3 | |
| ABCO/QUGA | ABCO | 1911 | 22 | 1.0 | 1954 | 43 | 8.5 | - | - | 1.5 | 3.7 | |
| Mean: | | | 38 | 5.0 | | 59 | 13.2 | | 40 | 5.7 | | |

---

[1] No outbreak was detected during the 1940-1960 period on the Questa Ranger District. Thus, these sites were assigned the lowest equal ranking, eg., (ranks 1 + 2 + 3 + 4 + 5 + 6) ÷ 6 = 3.5. The 1980s outbreak spread to the Peñasco sites only in 1985 or 1986, the last year of the tree-ring chronologies.

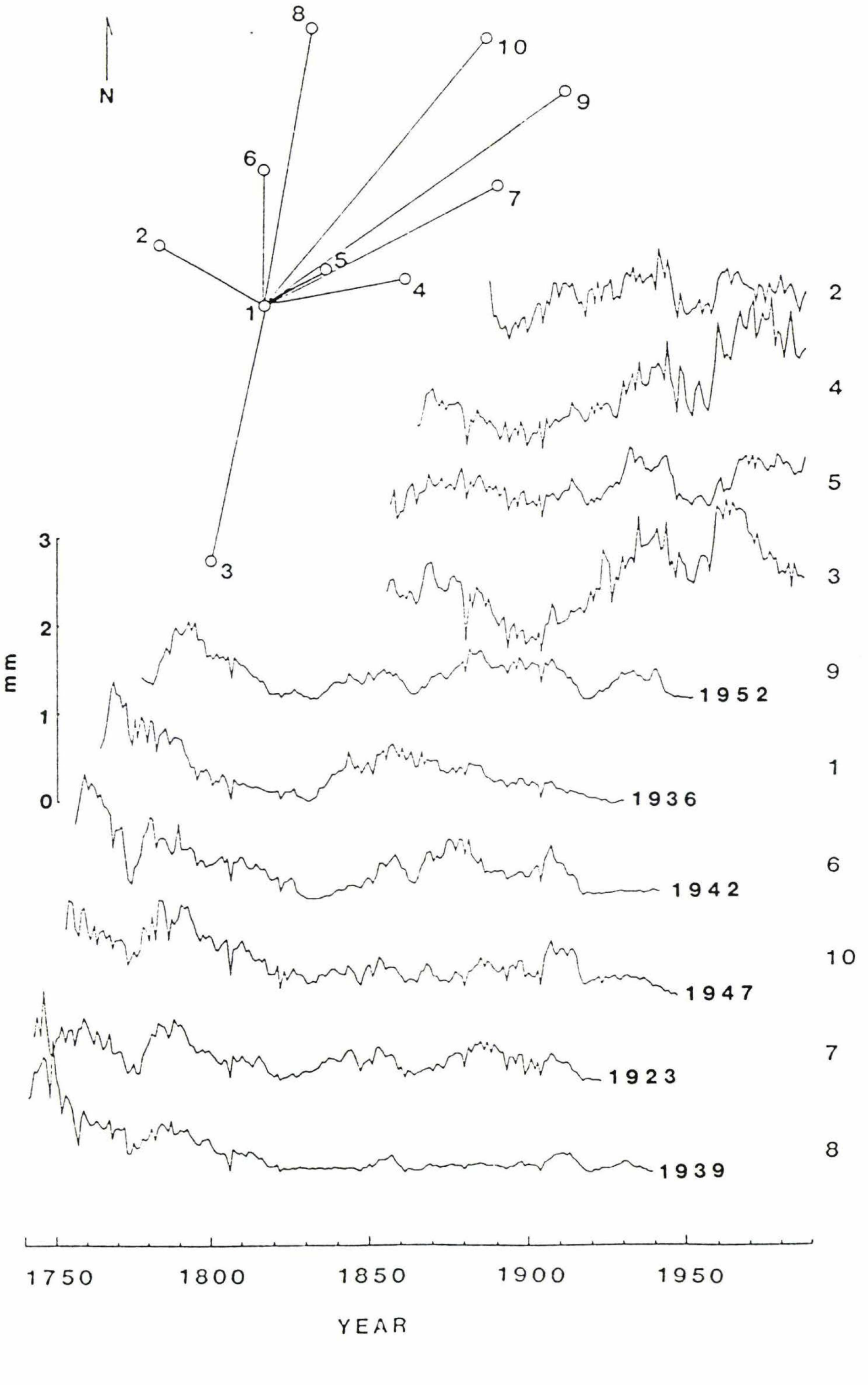
Although this comparison generally shows the hypothesized highest susceptible and vulnerable habitat type ABCO/ACGL having the greatest measured severity for this outbreak, it also happens that all three of these stands are on the Jemez Ranger District. At this time there seems to be too few stands to sort out different impacts among habitat types within Ranger Districts or watersheds. When all twenty pairs of stand chronologies (Douglas-fir and white fir) have been developed a thorough analyses involving sorting by habitat type, outbreak period and watersheds will be conducted. Additional measures of the budworm outbreak regime will also be compiled, such as periodic growth reduction, outbreak duration, and frequency of outbreaks (number of outbreaks per time period).

## PRELIMINARY RESULTS OF MORTALITY INVESTIGATION

Figure 12 shows the ring-width series from ten trees sampled at the Peralta High site. Tree number 1 was the initial dead tree that was sampled. It was a standing Douglas-fir snag with a dbh of 38 cm. Trees 2, 3, 4, and 5 were the nearest living trees to tree number 1. Trees 6 through 10 were other dead trees in the vicinity.

The outermost rings of the dead trees could not be exactly dated in all cases because of very reduced growth and decay. However, it is apparent from the approoximate dating of the outermost ring on trees 1, 6, 8, and 9 that they were probably killed in the 1940s to 1960s outbreak. The surviving trees (numbers 2, 3, 4, and 5) show sharply reduced growth during the 1940s and a substantial growth release after the mortality event.

Figure 12. Ring-width series from four living trees (2, 3, 4, 5) and six dead trees (1, 6, 7, 8, 9, 10) from the Peralta High stand on the Jemez Ranger District. Approximate death dates are indicated at the right of the dead tree series. Actual death dates may have been one or several years later. The diagram at upper left shows the spatial relationship of the 10 trees. Distance between tree 1 and 2 was 4.7m.



The outermost visible ring on tree number 7 was 1923. As with the other trees the actual death date may have been a one or several years later, because of missing rings in the last few years of highly reduced growth. It seems probable that this tree succumbed during the 1910-1925 outbreak.

Possible earlier outbreaks in the 1770s, 1820s, and 1860s are also visible as reduced growth (fig 12). The 29 other trees sampled along the transects in this stand have not been analyzed yet, however, it is expected that this site will provide a long record of repeated outbreaks. While sampling in this stand several trees were observed with three or four old "spike tops" protruding from crooked portions of their stems. It is likely that these "spikes" were caused by the topkilling effects of repeated spruce budworm outbreaks.

## DISCUSSION AND CONCLUSIONS

Tree-ring width chronologies from the twenty Douglas-fir and white fir collections from ten stands revealed a history of western spruce budworm outbreaks extending back several centuries before the present. Several of the chronologies have good sample depth back to about 1700 or the late 1600s. Analyses of outbreak severity reported here includes outbreaks recorded only in the twentieth century because an additional ten stands remain to be fully processed. It is felt that these pending results will provide additional evidence that is needed for identifying major outbreak periods within different watersheds and over the entire region.

Comparison of the corrected chronologies among all of the stands reveals that general periods of increased budworm activity, or "outbreaks", were usually region-wide. For example, in the twentieth century three major outbreak periods were recorded; the first in the late 1910s to 1920s, next in the 1940s to early 1960s, and finally the late 1970s to present. However, spatial and temporal variations in these outbreaks were observed. For example, the Questa Ranger District stands that have been analyzed do not show any definite evidence of a 1940s to 1960s outbreak. Also different stands apparently were infested at different times within general outbreak periods. For example, the Jemez stands were heavily defoliated in the early 1980s and appear now to be making a recovery, while the analyzed stands in the La Junta watershed (Peñasco Ranger District) were just becoming heavily defoliated at the time of sampling in 1987.

Due to the localized nature of outbreak timing within watersheds and specific stands it seems that further analyses of the relation between severity and habitat type, or other stand characteristics, will probably be most fruitful through comparison of tree-ring records within watersheds or Ranger Districts.

It is also evident that the size and age structure of stands will be an important factor to consider in the study of budworm outbreak histories within individual stands. Examples of two very different stands are Fenton Lake and Policarpio Canyon. The Fenton Lake stand is a relatively even-aged, young stand that probably established following a stand replacing fire in the early 1870s. Nearly all of the cored trees established in the late 1870s or 1880s. Also, the decaying remnants of an aspen stand was observed on the forest floor beneath this maturing stand. Because of the relatively recent origin of this stand no major outbreaks were recorded in the younger trees until the 1910s-1920s period. The most recent outbreak has resulted in very heavy mortality (exceeding 70% in some areas). It is likely that this stand is now primed for another fire.

In contrast, the Policarpio stand is older with many individuals that established in the late 1600s. Two other cohorts of host trees became established in the late 1800s and in the early 1900s. In general, this is an uneven-aged stand that appears to have been repeatedly attacked by budworm. Nevertheless, considering its longevity, this stand may be considered quite stable. Given these observations, some of the basic questions to be addressed by the overall project are becoming clearer. For example: Are there certain site and stand characteristics, and other historical disturbances (eg., fire), that are related to different types of budworm outbreak regimes? If so, what are these stand characteristics and historical interrelationships?

Ranking of the estimated severity of outbreaks in the twentieth century does not seem to provide any clear insights at this time, primarily because too few stands have been studied. However, with completion of the analyses of the remaining stands, this approach, as well as others, are expected to yield information that should be quite useful in answering the above questions.

The study of timing of past host tree mortality is producing positive results. Based on the case study described earlier in this report it seems that good success can be expected in efforts to determine approximate death dates of trees killed in past budworm outbreaks. Results from study of three additional sets of live and dead tree samples from two other stands should provide information on how future studies might quantify levels of mortality caused by past budworm outbreaks.

## LITERATURE CITED

Biondi, F. and T. W. Swetnam. 1988. Box-Jenkins models of forest interior tree-ring chronologies. Tree Ring Bull. 47:71-96.

Carlson, C. E., D. G. Fellin, and W. C. Schmidt. 1983. The western spruce budworm in northern Rocky Mountain forests: a review of ecology, insecticidal treatments and silvicultural practices. Pages 76-103, In: Management of Second Growth Forests, the State of Knowledge and Research Needs, O'Laughlin and R. D. Pfister eds., Montana For. Conserv. Exp. Stn., University of Montana, Missoula.

Daubenmire, R. 1968. Plant communities: A textbook of plant synecology. Harper and Row, New York. 300p.

DeVelice, R. L., J. A. Ludwig, W. H. Moir and F. Ronco, Jr. 1986. A classification of forest habitat types of northern New Mexico and southern Colorado. USDA Forest Service, Gen. Tech. Rep. RM-131. 59p.

Fritts, H. C. 1976. Tree rings and climate. Academic Press, London. 567 p.

Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service, Gen. Tech. Rep. RM-48. 7p.

Husch, B., C. I. Miller, and T. W. Beer. 1982. Forest mensuration. John Wiley and Sons, New York.

Lessard, G. 1975. The occurrence and control of the western spruce budworm in the Southwestern Region. USDA Forest Service, SW. Reg. For. Pest Manage. Rep. R-3 75-26. 11p.

Moir, W. H. and J. A. Ludwig. 1979. A classification of spruce-fir habitat types of Arizona and New Mexico. USDA Forest Service, Res. Pap. RM-207.

Pfister, R. D. and S. F. Arno. 1980. Classifying forest habitat types based on potential climax vegetation. For. Sci. 26:52-70.

Swetnam, T. W. 1987. A dendrochronological assessment of western spruce budworm, Choristoneura occidentalis Freeman, in the Southern Rocky Mountains. PhD diss., University of Arizona, Tucson. 213p.

Swetnam, T. W., M. A. Thompson, and E. K. Sutherland. 1985. Using dendrochronology to measure radial growth of defoliated trees. USDA Forest Service, Agric. Handbook 639. 39p.

Swetnam, T. W. and A. M. Lynch. (submitted to Forest Science). A tree-ring reconstruction of western spruce budworm history in the Southern Rocky Mountains.

Telfer, W. G. 1984. Western spruce budworm suppression and evaluation project using carbaryl--1977, Progess Report No. 7. USDA Forest Service, SW Reg. For. Pest Manage. Rep. R-3 84-7.

United States Department of Agriculture, Forest Service. 1987. Forest and woodland habitat types (Plant associations) of northern New Mexico and Arizona. Edition 2. Southwestern Region, Albuquerque.

Wigley, T. M. L., K. R. Briffa, and P. D. Jones. 1984. On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology. J. Clim. and Appl. Meteorol. 23(2):201-213.

Wulf, N. W. and C. E. Carlson. 1985. Generalized indexing model. Chapt. 6, pages 51-55. In: Managing Trees and Stands Susceptible to Western Spruce Budworm. M. H. Brooks, J. J. Colbert, R. G. Mitchell, and R. W. Stark, tech. coords. USDA Forest Service, Tech. Bull No. 1695.

Wulf, N. W. and R. G. Cates. 1985. Site and stand characteristics. Chapt. 4, pages 23-26, In: Managing Trees and Stands Susceptible to Western Spruce Budworm. M. H. Brooks, J. J. Colbert, R. G. Mitchell, and R. W. Stark, tech. coords. USDA Forest Service, Tech. Bull NO 1695.

# APPENDIX A

## CORRECTED HOST TREE-RING WIDTH INDEX CHRONOLOGIES

The period from 1600 to 1987 is listed for twenty chronologies. Column headings include three-letter codes for the sampled stands plus the letters DF or WF indicating whether the chronology is from the Douglas-fir or white fir collections from each stand, respectively. Note that most chronologies end in 1986, which was the last complete ring formed before sampling. The corrected chronologies from the Questa Ranger District end in 1981. This is because the most recent pine collections from this site have not been fully analyzed and an existing chronology developed from piñon trees from Cabresto Canyon, which ends in 1981, was used as a control in the correction procedure.

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1600 |  |  |  |  |  |  |  |  |  |  | 0.94 |  |  |  |  |  |  |  | 1.72 |  |
| 1601 |  |  |  |  |  |  |  |  |  |  | 1.15 |  |  |  |  |  |  |  | 1.26 |  |
| 1602 |  |  |  |  |  |  |  |  |  |  | 1.42 |  |  |  | 1.26 |  |  |  | 1.55 |  |
| 1603 |  |  |  |  |  |  |  |  |  |  | 1.46 |  |  |  | 1.50 |  |  |  | 0.98 |  |
| 1604 |  |  |  |  |  |  |  |  |  |  | 1.50 |  |  |  | 1.49 |  |  |  | 1.18 |  |
| 1605 |  |  |  |  |  |  |  |  |  |  | 1.23 |  |  |  | 0.99 |  |  |  | 0.93 |  |
| 1606 |  |  |  |  |  |  |  |  |  |  | 1.07 |  |  |  | 0.98 |  |  |  | 1.05 |  |
| 1607 |  |  |  |  |  |  |  |  |  |  | 1.15 |  |  |  | 0.88 |  |  |  | 0.76 |  |
| 1608 |  |  |  |  |  |  |  |  |  |  | 1.18 |  |  |  | 1.20 |  |  |  | 1.11 |  |
| 1609 |  |  |  |  |  |  |  |  |  |  | 0.82 |  |  |  | 0.90 |  |  |  | 0.57 |  |
| 1610 |  |  |  |  |  |  |  |  |  |  | 0.75 |  |  |  | 0.17 |  |  |  | 0.29 |  |
| 1611 |  |  |  |  |  |  |  |  |  |  | 0.94 |  |  |  | 0.33 |  |  |  | 0.50 |  |
| 1612 |  |  |  |  |  |  |  |  |  |  | 0.56 |  |  |  | 0.14 |  |  |  | 0.47 |  |
| 1613 |  |  |  |  |  |  |  |  |  |  | 0.73 |  |  |  | 0.35 |  |  |  | 0.55 |  |
| 1614 |  |  |  |  |  |  |  |  |  |  | 0.65 |  |  |  | 0.77 |  |  |  | 0.89 |  |
| 1615 |  |  |  |  |  |  |  |  |  |  | 0.74 |  |  |  | 0.90 |  |  |  | 0.98 |  |
| 1616 |  |  |  |  |  |  |  |  |  |  | 0.97 |  |  |  | 1.17 |  |  |  | 0.89 |  |
| 1617 |  |  |  |  |  |  |  |  |  |  | 0.84 |  |  |  | 0.45 |  |  |  | 0.56 |  |
| 1618 |  |  |  |  |  |  |  |  |  |  | 0.53 |  |  |  | 0.34 |  |  |  | 0.47 |  |
| 1619 |  |  |  |  |  |  |  |  |  |  | 1.00 |  |  |  | 0.88 |  |  |  | 0.65 |  |
| 1620 |  |  |  |  |  |  |  |  |  |  | 0.87 |  |  |  | 1.29 |  |  |  | 0.31 |  |
| 1621 |  |  |  |  |  |  |  |  |  |  | 0.64 |  |  |  | 1.35 |  |  |  | 0.08 |  |
| 1622 |  |  |  |  |  |  |  |  |  |  | 0.95 |  |  |  | 1.55 |  |  |  | 0.43 |  |
| 1623 |  |  |  |  |  |  |  |  |  |  | 1.13 |  |  |  | 1.40 |  |  |  | 0.64 |  |
| 1624 |  |  |  |  |  |  |  |  |  |  | 0.90 |  |  |  | 1.59 |  |  |  | 1.25 |  |
| 1625 |  |  |  |  |  |  |  |  |  |  | 0.97 |  |  |  | 1.37 |  |  |  | 1.21 |  |
| 1626 |  |  |  |  |  |  |  |  |  |  | 0.82 |  |  |  | 1.37 |  |  |  | 1.12 |  |
| 1627 |  |  |  |  |  |  |  |  |  |  | 0.93 |  |  |  | 1.19 |  |  |  | 1.27 |  |
| 1628 |  |  |  |  |  |  |  |  |  |  | 0.92 |  |  |  | 1.55 |  |  |  | 1.40 |  |
| 1629 |  |  |  |  |  |  |  |  |  |  | 0.94 |  |  |  | 0.53 |  |  |  | 0.85 |  |
| 1630 |  |  |  |  |  |  |  |  |  |  | 1.21 |  |  |  | 0.92 | 1.73 |  |  | 1.32 |  |
| 1631 |  |  |  |  |  |  |  |  |  |  | 1.18 |  |  |  | 1.56 | 0.38 |  |  | 0.60 |  |
| 1632 |  |  |  |  |  |  |  |  |  |  | 1.32 |  |  |  | 1.17 | 1.24 |  |  | 0.76 |  |
| 1633 |  |  |  |  |  |  |  |  |  |  | 0.92 |  |  |  | 0.95 | 1.40 |  |  | 0.83 |  |
| 1634 |  |  |  |  |  |  |  |  |  |  | 1.23 |  |  |  | 0.74 | 1.27 |  |  | 0.89 |  |
| 1635 |  |  |  |  |  |  |  |  |  |  | 0.90 |  |  |  | 1.41 | 1.28 |  |  | 0.58 |  |
| 1636 |  |  |  |  |  |  |  |  |  |  | 1.15 |  |  |  | 1.32 | 1.03 |  |  | 1.03 |  |
| 1637 |  |  |  |  |  |  |  |  |  |  | 1.12 |  |  |  | 1.16 | 1.17 |  |  | 0.99 |  |
| 1638 |  |  |  |  |  |  |  |  |  |  | 1.11 |  |  |  | 1.87 | 1.58 |  |  | 1.03 |  |
| 1639 |  |  |  |  |  |  |  |  |  |  | 0.95 |  |  |  | 1.19 | 0.84 |  |  | 1.28 |  |
| 1640 |  |  |  |  |  |  |  |  |  |  | 0.96 |  |  |  | 1.16 | 0.71 |  |  | 1.38 |  |
| 1641 |  |  |  |  |  |  |  |  |  |  | 0.93 |  |  |  | 1.50 | 1.13 |  |  | 1.14 |  |
| 1642 |  |  |  |  |  |  |  |  |  |  | 0.80 |  |  |  | 0.73 | 0.53 |  |  | 0.95 |  |
| 1643 |  |  |  |  |  |  |  |  |  |  | 0.72 |  |  |  | 0.74 | 0.57 |  |  | 0.83 |  |
| 1644 |  |  |  |  |  |  |  |  |  |  | 0.73 |  |  |  | 0.79 | 0.50 |  |  | 0.90 |  |
| 1645 |  |  |  |  |  |  |  |  |  |  | 0.96 |  |  |  | 0.56 | 0.41 |  |  | 0.54 |  |
| 1646 |  |  |  |  |  |  |  |  |  |  | 0.88 |  |  |  | 1.05 | 0.63 |  |  | 1.04 |  |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1647 | | | | | | | | | | | 0.72 | | | | 1.37 | 1.06 | | | 0.79 | |
| 1648 | | | | | | | | | | | 1.25 | | | | 1.44 | 1.49 | | | 1.15 | |
| 1649 | | | | | | | | | | | 0.89 | | | | 1.14 | 1.02 | | | 1.08 | |
| 1650 | | | | | | | | | | | 0.69 | | | | 1.55 | 1.21 | | | 0.82 | |
| 1651 | | | | | | | | | | | 1.08 | | | | 1.24 | 0.97 | | | 0.61 | |
| 1652 | | | | | | | | | | | 0.90 | | | | 1.19 | 1.28 | | | 0.81 | |
| 1653 | | | | | | | | | | | 1.21 | | | | 1.77 | 2.19 | | | 1.43 | |
| 1654 | | | | | | | | | | | 1.15 | | | | 1.36 | 1.57 | | | 0.48 | |
| 1655 | | | | | | | | | | | 1.04 | | | | 1.02 | 1.10 | | | 1.35 | |
| 1656 | | | | | | | | | | | 1.10 | | 0.06 | | 0.74 | 0.57 | | | 1.01 | |
| 1657 | | | | | | | | | | | 1.21 | | 1.12 | | 1.22 | 1.32 | | | 1.54 | |
| 1658 | | | | | | | | | | | 1.31 | | 1.24 | | 1.08 | 0.89 | | | 1.05 | |
| 1659 | | | | | | | | | | | 0.92 | | 0.77 | | 0.90 | 0.88 | | | 1.31 | |
| 1660 | | | | | | | | | | | 1.11 | | 0.76 | | 0.86 | 0.84 | | | 1.09 | |
| 1661 | | | | | | | | | | | 1.29 | | 0.60 | | 0.97 | 1.12 | | | 0.87 | |
| 1662 | | | | | | | | | | | 1.12 | | 0.27 | | 0.90 | 0.78 | | | 0.39 | |
| 1663 | | | | | | | | | | | 0.94 | | 0.57 | | 1.10 | 0.95 | | | 0.83 | |
| 1664 | | | | | | | | | | | 0.98 | | 0.91 | | 1.17 | 1.26 | | | 1.40 | |
| 1665 | | | | | | | | | | | 0.90 | | 0.91 | | 0.97 | 1.17 | | | 1.01 | |
| 1666 | | | | | | | | | | | 1.18 | | 0.85 | | 1.03 | 1.04 | | | 0.95 | |
| 1667 | | | | | | | | | | | 0.99 | | 1.30 | | 1.36 | 1.39 | | | 1.29 | |
| 1668 | | | | | | | | | | | 0.83 | | 0.94 | | 1.03 | 1.11 | | | 0.70 | |
| 1669 | | | | | | | | | | | 0.81 | | 0.74 | | 0.81 | 0.97 | | | 0.88 | |
| 1670 | | | | | | | | | | | 0.78 | | 0.80 | | 1.05 | 1.17 | | | 1.05 | |
| 1671 | | | | | | | | | | | 1.23 | | 1.05 | | 1.23 | 1.54 | | | 0.91 | |
| 1672 | | | | | | | | | | | 0.89 | | 1.02 | | 0.98 | 1.26 | | | 0.62 | |
| 1673 | | | | | | | | | | | 1.22 | | 0.91 | | 0.93 | 1.16 | | | 1.01 | |
| 1674 | | | | | | | | | | | 1.09 | | 1.24 | | 1.04 | 1.35 | | | 1.03 | |
| 1675 | | | | | | | | | | | 1.30 | | 1.32 | | 1.28 | 1.46 | | | 0.80 | |
| 1676 | | | | | | | | | | | 1.26 | | 1.71 | | 1.47 | 1.87 | | | 1.57 | |
| 1677 | | | | | | | | | | | 1.20 | | 1.29 | | 1.36 | 1.62 | | | 1.10 | |
| 1678 | | | | | | | | | | | 1.17 | | 1.62 | | 1.29 | 1.61 | | | 1.49 | |
| 1679 | | | | | | | | | | | 1.39 | | 1.29 | | 1.22 | 1.29 | | | 0.78 | |
| 1680 | | | | | | | | | | | 0.92 | | 1.38 | | 1.06 | 1.44 | | | 0.87 | |
| 1681 | | | | | | | | | | | 0.76 | 0.74 | 1.29 | | 0.92 | 1.00 | | | 0.92 | |
| 1682 | | | | | | | | | | | 1.24 | 1.55 | 1.77 | | 1.20 | 1.79 | | | 1.00 | |
| 1683 | | | | | | | | | | | 0.60 | 0.63 | 1.51 | | 1.01 | 1.48 | | | 1.06 | |
| 1684 | | | | | | | | | | | 0.85 | 0.80 | 1.17 | | 0.82 | 1.27 | | | 1.40 | |
| 1685 | | | | | | | | | | | 0.63 | 1.14 | 1.37 | | 1.11 | 1.66 | 1.89 | | 1.34 | |
| 1686 | | | | | | | | | | | 0.89 | 0.76 | 1.47 | | 1.36 | 1.75 | 1.19 | | 1.09 | |
| 1687 | | | | | | | | | | | 0.83 | 0.88 | 1.65 | | 1.18 | 1.78 | 0.62 | | 1.08 | |
| 1688 | | | | | | | | | | | 1.08 | 0.71 | 1.18 | | 1.05 | 1.45 | 0.37 | | 1.21 | |
| 1689 | | | | | | | | | | | 1.13 | 0.84 | 1.62 | | 1.08 | 1.53 | 0.50 | | 1.09 | |
| 1690 | | | | | | | | | | | 1.38 | 1.12 | 1.55 | | 1.28 | 1.37 | 1.04 | | 1.11 | |
| 1691 | | | | | | | | | | | 1.08 | 0.95 | 1.53 | | 1.19 | 1.18 | 0.91 | | 1.07 | |
| 1692 | | | | | | | | | | | 1.37 | 1.33 | 1.95 | | 1.12 | 1.12 | 0.84 | | 0.63 | |
| 1693 | | | | | | | | | | | 1.15 | 0.58 | 1.59 | | 0.99 | 0.86 | 0.80 | | 1.66 | |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1694 | | | | | | | | | | | 0.81 | 0.52 | 1.09 | | 0.86 | 0.71 | 0.93 | | 0.48 | |
| 1695 | | | | | | | | | | | 0.66 | 0.42 | 1.55 | | 1.16 | 1.01 | 1.35 | | 1.13 | |
| 1696 | | | | | | | | | | | 0.81 | 0.77 | 1.35 | | 1.20 | 1.14 | 1.21 | | 1.17 | |
| 1697 | | | | | | | | | | | 0.85 | 1.08 | 1.76 | | 1.22 | 0.89 | 1.02 | | 1.61 | |
| 1698 | | | | | | | | | | | 0.86 | 0.71 | 1.87 | | 1.34 | 1.09 | 1.51 | | 1.32 | |
| 1699 | | | | | | | | | | | 0.86 | 0.96 | 1.28 | | 1.10 | 0.81 | 0.87 | | 1.01 | |
| 1700 | | | | | | | | | | | 1.17 | 1.43 | 1.40 | | 1.17 | 1.05 | 0.81 | | 0.90 | |
| 1701 | | | | | | | | | | | 0.98 | 0.95 | 1.24 | | 1.07 | 0.81 | 0.77 | | 1.29 | |
| 1702 | 1.19 | | | | | | | | | | 1.11 | 1.20 | 1.14 | | 1.16 | 0.89 | 0.78 | | 1.05 | |
| 1703 | 1.04 | | | | | | | | | | 1.37 | 1.08 | 1.47 | | 1.34 | 1.09 | 0.76 | | 1.71 | |
| 1704 | 0.83 | | | | | | | | | | 1.51 | 1.50 | 1.05 | | 1.10 | 1.00 | 0.79 | | 1.32 | |
| 1705 | 0.46 | | | | | | 1.27 | | | | 1.17 | 1.85 | 1.05 | | 1.13 | 1.11 | 0.76 | | 0.93 | |
| 1706 | 0.25 | | | | | | 0.95 | | | | 0.75 | 1.13 | 1.60 | | 1.41 | 1.41 | 1.16 | | 0.92 | |
| 1707 | 1.55 | | | | | | 1.27 | | | | 1.35 | 1.52 | 1.48 | | 1.20 | 1.11 | 1.26 | | 1.10 | |
| 1708 | 1.04 | | | | | | 0.79 | | | | 1.20 | 1.42 | 1.52 | | 1.21 | 1.35 | 1.13 | | 1.15 | |
| 1709 | 1.70 | | | | | | 0.73 | | | | 1.13 | 1.28 | 1.10 | | 1.10 | 1.31 | 0.89 | | 0.81 | |
| 1710 | 0.13 | | | | | | 0.92 | | | | 0.87 | 1.10 | 1.68 | | 1.05 | 1.15 | 1.07 | | 0.91 | |
| 1711 | 0.37 | | | | | | 1.16 | | | | 0.94 | 1.13 | 1.29 | | 1.01 | 0.83 | 1.67 | | 0.83 | |
| 1712 | 0.15 | | | | | | 0.93 | | | | 1.01 | 1.45 | 1.06 | | 1.09 | 0.85 | 1.40 | | 1.11 | |
| 1713 | 0.32 | | | | | | 0.71 | | | | 1.26 | 1.55 | 0.70 | | 0.71 | 0.58 | 1.52 | | 1.24 | |
| 1714 | 0.50 | | | | | | 1.06 | | | | 1.18 | 1.18 | 0.74 | | 0.74 | 0.71 | 1.55 | | 0.87 | |
| 1715 | 0.68 | | | | | | 1.34 | | | | 1.05 | 1.11 | 1.22 | | 0.91 | 0.81 | 1.43 | | 0.74 | |
| 1716 | 0.30 | | | | | | 1.04 | | | | 0.79 | 0.71 | 0.93 | | 0.79 | 0.80 | 1.09 | | 0.47 | |
| 1717 | 0.61 | | | | | | 1.01 | | | | 0.94 | 0.69 | 0.58 | | 1.13 | 1.16 | 1.18 | | 0.69 | |
| 1718 | 0.64 | | | | | | 0.85 | | | | 0.53 | 0.28 | 0.53 | | 0.97 | 0.90 | 1.21 | | 0.40 | 0.62 |
| 1719 | 1.19 | | | | | | 0.91 | | | | 1.04 | 1.34 | 0.86 | | 1.05 | 1.14 | 0.96 | | 1.03 | 1.24 |
| 1720 | 0.98 | | | | | | 0.95 | | | | 0.57 | 0.91 | 0.50 | | 0.68 | 0.84 | 0.98 | | 0.54 | 0.24 |
| 1721 | 1.89 | | | | | | 1.14 | | | | 1.00 | 1.66 | 1.05 | | 0.99 | 0.96 | 1.33 | | 1.18 | 1.21 |
| 1722 | 0.76 | | | | | | 1.10 | | | | 0.94 | 1.57 | 1.12 | | 0.66 | 0.54 | 1.25 | | 1.28 | 1.45 |
| 1723 | 1.10 | | | | | | 1.00 | | | | 0.96 | 1.71 | 0.45 | | 0.51 | 0.51 | 0.71 | | 1.17 | 1.21 |
| 1724 | 1.04 | | | | | | 1.28 | | | | 0.97 | 1.64 | 0.49 | | 0.41 | 0.38 | 1.06 | | 1.13 | 1.20 |
| 1725 | 1.27 | | | | | | 1.04 | | | | 0.92 | 1.23 | 0.32 | | 0.47 | 0.50 | 0.78 | | 1.10 | 1.16 |
| 1726 | 0.54 | | | | | | 0.94 | | | | 1.04 | 1.44 | 0.56 | | 0.60 | 0.49 | 1.19 | | 1.51 | 0.92 |
| 1727 | 0.99 | | | | | | 0.83 | | | | 1.22 | 1.43 | 0.68 | | 0.52 | 0.46 | 0.85 | | 1.60 | 1.39 |
| 1728 | 0.91 | | | | | | 0.84 | | | | 1.06 | 1.57 | 0.83 | | 0.87 | 0.94 | 0.94 | | 1.26 | 1.38 |
| 1729 | 1.74 | | | | | | 1.01 | | | | 0.96 | 1.12 | 0.87 | | 0.75 | 0.81 | 1.01 | | 0.92 | 0.97 |
| 1730 | 0.81 | | | | | | 0.84 | | | | 0.94 | 1.27 | 0.92 | | 0.75 | 0.80 | 0.54 | | 1.05 | 1.07 |
| 1731 | 1.43 | | | | | | 1.47 | | | | 0.87 | 1.25 | 1.23 | | 0.75 | 0.78 | 0.53 | | 0.96 | 0.98 |
| 1732 | 1.67 | | | | | | 1.31 | | | | 0.82 | 1.06 | 1.19 | | 0.88 | 0.90 | 0.60 | | 0.73 | 0.67 |
| 1733 | 0.86 | | | | | | 1.50 | | | | 1.00 | 1.02 | 1.00 | | 0.90 | 0.84 | 0.81 | | 0.82 | 0.85 |
| 1734 | 1.24 | | | | | | 1.33 | | | | 0.92 | 1.07 | 0.85 | | 0.84 | 0.88 | 0.40 | | 1.07 | 0.87 |
| 1735 | 1.53 | | | | | | 1.22 | | | | 1.01 | 1.15 | 1.10 | | 1.18 | 1.14 | 0.81 | | 0.88 | 0.88 |
| 1736 | 1.63 | | | | | | 0.94 | | | | 0.78 | 1.06 | 0.79 | | 1.13 | 0.95 | 0.51 | | 0.91 | 0.70 |
| 1737 | 1.31 | | | | 0.99 | | 1.08 | | | | 0.95 | 1.17 | 0.72 | | 0.83 | 0.76 | 0.73 | | 0.80 | 0.86 |
| 1738 | 1.83 | | | | 1.00 | | 0.79 | | | | 0.79 | 0.83 | 0.78 | | 0.68 | 0.61 | 0.33 | | 0.84 | 0.83 |
| 1739 | 1.69 | | | | 1.35 | | 1.09 | | | | 0.89 | 0.96 | 1.38 | | 1.28 | 1.22 | 1.02 | | 0.74 | 0.33 |
| 1740 | 1.43 | | | | 0.97 | | 1.20 | | | | 0.98 | 0.93 | 1.03 | | 0.96 | 0.88 | 0.66 | | 0.85 | 0.57 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1741 | 1.32 | | | | 1.09 | | 1.01 | | | | 0.85 | 0.77 | 1.22 | | 1.19 | 1.12 | 0.87 | | 0.63 | 0.33 |
| 1742 | 1.27 | | | | 0.81 | | 0.96 | | | | 0.89 | 0.43 | 1.22 | | 1.10 | 0.98 | 0.81 | | 0.53 | 0.21 |
| 1743 | 1.41 | | | | 1.09 | | 0.95 | | | | 1.02 | 0.63 | 1.26 | | 1.11 | 0.94 | 0.51 | | 1.13 | 0.55 |
| 1744 | 1.69 | | | | 1.38 | | 1.25 | | | | 1.30 | 0.88 | 1.21 | | 1.06 | 0.76 | 0.63 | | 1.21 | 0.73 |
| 1745 | 1.09 | | | | 0.93 | | 1.08 | | | | 0.90 | 0.57 | 1.16 | | 1.30 | 1.06 | 0.75 | | 1.11 | 0.59 |
| 1746 | 1.24 | | | | 0.88 | | 1.07 | | | | 0.77 | 0.63 | 0.96 | | 0.74 | 0.72 | 0.67 | | 1.26 | 0.79 |
| 1747 | 0.66 | | | | 0.79 | | 0.82 | | | | 0.90 | 0.33 | 1.04 | | 0.91 | 0.72 | 0.73 | | 1.15 | 0.79 |
| 1748 | 1.12 | | | | 1.28 | | 0.66 | | | | 1.30 | 1.28 | 1.15 | | 0.96 | 0.95 | 1.32 | | 1.41 | 1.22 |
| 1749 | 0.76 | | | | 0.93 | | 0.75 | | | | 0.89 | 0.76 | 0.52 | | 0.41 | 0.35 | 0.40 | | 1.28 | 1.11 |
| 1750 | 0.49 | | | | 1.38 | | 1.05 | | | | 0.92 | 0.64 | 0.65 | | 0.67 | 0.62 | 0.53 | | 0.96 | 0.96 |
| 1751 | 0.46 | | | | 1.36 | | 1.09 | | | | 0.90 | 0.56 | 0.79 | | 1.00 | 1.00 | 0.58 | | 1.29 | 0.84 |
| 1752 | 1.21 | | | | 1.68 | | 1.27 | | | | 0.99 | 1.04 | 1.05 | | 1.10 | 1.04 | 1.07 | | 0.72 | 0.60 |
| 1753 | 0.90 | | | | 1.34 | | 1.22 | | | | 0.80 | 0.39 | 0.88 | | 1.04 | 1.13 | 0.72 | | 1.14 | 0.83 |
| 1754 | 0.72 | | | | 1.32 | | 1.01 | | | | 0.74 | 0.00 | 0.53 | | 0.72 | 0.61 | 0.56 | | 1.00 | 0.66 |
| 1755 | 1.05 | | | | 1.37 | | 1.12 | | | | 1.12 | 0.24 | 0.67 | | 0.86 | 0.80 | 0.65 | | 1.54 | 0.78 |
| 1756 | 0.95 | | | | 1.52 | | 1.26 | | | | 1.28 | 0.62 | 1.21 | | 1.16 | 1.06 | 1.26 | | 1.35 | 0.91 |
| 1757 | 1.04 | | | | 1.53 | | 0.97 | | | | 1.36 | 0.57 | 1.21 | | 0.97 | 1.12 | 1.19 | | 1.51 | 1.33 |
| 1758 | 1.08 | | | | 1.61 | | 1.09 | | | | 1.28 | 0.48 | 1.07 | | 1.18 | 1.22 | 0.84 | | 1.25 | 1.05 |
| 1759 | 1.37 | | | | 1.63 | | 1.34 | | | | 0.94 | 0.31 | 1.30 | | 1.39 | 1.37 | 1.23 | | 0.96 | 0.76 |
| 1760 | 1.13 | | | | 1.37 | | 1.10 | | 0.60 | 0.29 | 0.93 | 0.10 | 1.21 | | 1.20 | 1.26 | 1.09 | | 0.91 | 0.78 |
| 1761 | 0.92 | | | | 1.17 | | 1.08 | | 0.71 | 0.50 | 0.84 | 0.06 | 0.73 | | 1.03 | 0.95 | 1.31 | | 1.15 | 1.45 |
| 1762 | 0.93 | | | | 1.04 | | 1.04 | | 0.73 | 0.61 | 1.09 | 0.00 | 0.65 | | 0.95 | 0.68 | 1.38 | | 1.19 | 1.04 |
| 1763 | 1.09 | | | | 1.31 | | 1.18 | | 1.21 | 1.17 | 1.36 | 0.69 | 1.21 | | 1.08 | 0.95 | 1.47 | | 1.32 | 1.57 |
| 1764 | 0.81 | | | | 1.12 | | 1.00 | | 1.20 | 1.16 | 1.29 | 0.59 | 0.10 | | 0.62 | 0.54 | 0.93 | | 1.76 | 1.94 |
| 1765 | 0.51 | | | | 1.04 | | 1.25 | | 1.41 | 1.33 | 1.20 | 0.70 | 0.65 | | 1.07 | 0.77 | 1.37 | | 1.28 | 1.27 |
| 1766 | 0.19 | | | | 0.72 | | 1.76 | | 1.11 | 0.94 | 1.12 | 0.13 | 0.52 | | 1.12 | 0.89 | 1.46 | | 1.70 | 1.82 |
| 1767 | 0.28 | | | | 1.15 | | 1.52 | | 1.11 | 1.01 | 1.01 | 0.06 | 0.65 | | 1.28 | 1.02 | 1.93 | | 0.89 | 0.96 |
| 1768 | 0.71 | | | | 0.99 | | 1.25 | | 0.71 | 0.60 | 0.77 | 0.00 | 0.70 | | 1.31 | 1.20 | 2.61 | | 1.25 | 1.31 |
| 1769 | 1.03 | | | | 1.15 | | 1.32 | | 1.03 | 1.03 | 0.95 | 0.22 | 0.53 | | 1.03 | 1.11 | 1.70 | | 1.48 | 1.40 |
| 1770 | 1.10 | | | | 1.07 | | 1.56 | | 0.92 | 0.87 | 0.93 | 0.30 | 0.49 | | 1.06 | 1.14 | 2.02 | | 1.23 | 1.46 |
| 1771 | 1.50 | | | | 0.86 | | 1.47 | | 0.45 | 0.54 | 0.64 | 0.00 | 0.23 | | 1.04 | 1.10 | 1.57 | | 1.45 | 1.51 |
| 1772 | 1.25 | | | | 0.74 | | 1.07 | | 0.53 | 0.66 | 0.74 | 0.00 | 0.66 | | 0.98 | 1.08 | 1.46 | | 1.08 | 0.95 |
| 1773 | 1.24 | | | | 1.05 | | 0.89 | | 0.87 | 0.80 | 0.84 | 0.41 | 0.53 | | 0.63 | 0.65 | 0.99 | | 1.23 | 1.29 |
| 1774 | 1.19 | | | | 0.64 | | 0.93 | | 1.25 | 1.04 | 0.95 | 0.63 | 0.34 | | 0.60 | 0.75 | 0.64 | | 1.23 | 1.27 |
| 1775 | 1.15 | | | | 1.00 | | 1.05 | | 1.21 | 1.20 | 0.84 | 0.66 | 0.67 | | 0.72 | 0.81 | 1.17 | | 0.96 | 1.04 |
| 1776 | 0.87 | | | | 0.73 | | 0.85 | | 1.23 | 1.16 | 0.82 | 0.58 | 0.64 | | 0.87 | 1.01 | 1.08 | | 1.16 | 1.77 |
| 1777 | 0.98 | | | | 1.00 | | 0.80 | | 1.21 | 1.18 | 0.86 | 0.51 | 0.90 | | 1.11 | 1.20 | 1.19 | | 1.03 | 1.31 |
| 1778 | 0.96 | | | | 1.23 | | 0.94 | | 0.92 | 0.91 | 0.92 | 0.45 | 0.85 | | 1.02 | 1.05 | 0.84 | | 0.71 | 0.91 |
| 1779 | 1.16 | | | | 1.16 | | 0.87 | | 1.16 | 1.05 | 0.94 | 0.81 | 1.01 | | 0.99 | 1.10 | 1.17 | | 0.90 | 0.94 |
| 1780 | 1.29 | | | | 1.55 | | 1.11 | | 1.41 | 1.42 | 0.93 | 0.94 | 1.36 | | 1.12 | 1.31 | 1.29 | | 1.07 | 0.98 |
| 1781 | 1.14 | | | | 1.40 | | 1.01 | | 1.13 | 1.27 | 0.85 | 0.73 | 1.21 | | 0.93 | 1.11 | 1.10 | | 0.84 | 0.67 |
| 1782 | 1.26 | | | | 1.20 | | 0.98 | | 0.89 | 0.91 | 1.09 | 0.54 | 1.57 | | 1.41 | 1.55 | 1.42 | | 1.09 | 0.87 |
| 1783 | 0.82 | | | | 1.09 | | 0.94 | | 0.92 | 0.96 | 1.32 | 0.42 | 1.37 | | 1.20 | 1.18 | 1.44 | | 0.96 | 0.99 |
| 1784 | 0.71 | | | | 1.15 | | 0.74 | | 0.59 | 0.77 | 0.91 | 0.00 | 1.05 | | 1.19 | 0.98 | 1.12 | | 0.73 | 1.10 |
| 1785 | 1.32 | | | | 1.63 | | 1.16 | | 1.06 | 1.14 | 1.39 | 0.77 | 1.32 | | 1.25 | 1.23 | 1.17 | | 1.31 | 1.66 |
| 1786 | 1.11 | | | | 1.19 | | 0.80 | | 1.16 | 1.29 | 1.04 | 0.57 | 0.94 | | 0.90 | 1.05 | 0.77 | | 1.07 | 1.48 |
| 1787 | 0.87 | | | | 1.04 | | 0.85 | | 0.77 | 0.97 | 1.11 | 0.12 | 0.99 | | 1.09 | 1.06 | 1.06 | | 0.99 | 1.22 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1788 | 1.13 | | | | 1.11 | | 1.01 | | 1.07 | 1.16 | 1.60 | 0.32 | 0.91 | | 1.04 | 1.04 | 0.66 | | 0.99 | 1.01 |
| 1789 | 0.79 | | | | 1.20 | | 0.86 | | 1.19 | 1.32 | 1.46 | 0.66 | 0.98 | | 0.75 | 0.87 | 0.86 | | 0.92 | 0.97 |
| 1790 | 0.54 | | | | 0.94 | | 1.26 | | 1.24 | 1.30 | 1.36 | 0.27 | 1.06 | | 1.40 | 1.39 | 1.07 | | 0.90 | 0.90 |
| 1791 | 0.78 | | | | 1.00 | | 1.37 | | 0.96 | 1.16 | 1.37 | 0.13 | 0.75 | | 1.15 | 0.95 | 1.04 | | 1.15 | 1.21 |
| 1792 | 0.91 | | | | 0.87 | | 1.07 | | 1.10 | 1.38 | 1.37 | 0.34 | 1.00 | | 1.11 | 1.03 | 1.11 | | 1.24 | 1.31 |
| 1793 | 0.60 | | | | 0.55 | | 1.00 | | 1.46 | 1.66 | 1.41 | 0.64 | 0.49 | | 0.74 | 0.81 | 0.70 | | 1.56 | 1.98 |
| 1794 | 1.06 | | | | 0.75 | | 0.80 | | 1.24 | 1.35 | 1.19 | 0.82 | 0.81 | | 0.86 | 0.58 | 0.98 | | 1.30 | 1.54 |
| 1795 | 0.67 | | | | 0.80 | | 1.03 | | 1.26 | 1.36 | 1.16 | 0.76 | 0.14 | | 0.64 | 0.44 | 0.74 | | 1.15 | 1.13 |
| 1796 | 0.88 | | | | 0.71 | | 0.82 | | 1.21 | 1.27 | 1.27 | 0.73 | 0.19 | | 0.82 | 0.76 | 0.81 | | 1.27 | 1.32 |
| 1797 | 1.15 | | | | 0.81 | | 0.94 | | 0.99 | 1.02 | 1.03 | 0.71 | 0.63 | | 1.17 | 1.09 | 1.02 | | 0.91 | 0.78 |
| 1798 | 1.26 | | | | 0.76 | | 1.20 | | 0.74 | 0.83 | 0.72 | 0.32 | 0.38 | | 0.97 | 0.79 | 0.75 | | 0.60 | 0.55 |
| 1799 | 0.87 | | | | 0.57 | | 0.94 | | 0.86 | 1.04 | 0.87 | 0.41 | 0.26 | | 0.48 | 0.59 | 0.54 | | 0.91 | 0.93 |
| 1800 | 0.93 | | | | 0.45 | | 0.93 | | 0.95 | 1.11 | 0.95 | 0.25 | 0.39 | | 0.83 | 0.61 | 0.89 | | 1.02 | 1.02 |
| 1801 | 0.92 | | | | 0.89 | | 1.31 | | 1.03 | 1.09 | 1.07 | 0.78 | 1.15 | | 1.17 | 1.12 | 1.32 | | 0.97 | 0.90 |
| 1802 | 0.73 | | | | 0.64 | | 1.22 | | 1.08 | 1.09 | 0.79 | 0.48 | 0.55 | | 0.73 | 0.72 | 0.68 | | 0.65 | 0.89 |
| 1803 | 0.85 | | | | 0.47 | | 1.10 | | 0.88 | 0.94 | 0.51 | 0.06 | 0.35 | | 0.67 | 0.72 | 0.82 | | 0.52 | 0.77 |
| 1804 | 1.03 | | | | 0.55 | | 1.02 | | 0.90 | 0.95 | 0.80 | 0.17 | 0.68 | | 1.03 | 1.03 | 1.13 | | 0.64 | 1.07 |
| 1805 | 1.17 | | | | 0.98 | | 1.39 | | 1.24 | 1.15 | 0.92 | 0.50 | 0.43 | | 0.71 | 0.54 | 0.94 | | 0.68 | 0.58 |
| 1806 | 1.12 | | | | 0.95 | | 1.52 | | 0.76 | 0.68 | 0.64 | 0.24 | 0.61 | | 0.59 | 0.57 | 1.19 | | 0.51 | 0.82 |
| 1807 | 1.09 | | | | 0.52 | | 1.17 | | 1.18 | 0.93 | 0.82 | 0.29 | 0.77 | | 1.29 | 1.02 | 0.97 | | 0.81 | 1.22 |
| 1808 | 1.24 | 0.63 | | | 0.87 | | 1.33 | | 1.16 | 1.09 | 1.04 | 0.69 | 0.83 | | 1.28 | 1.18 | 1.18 | | 0.99 | 1.59 |
| 1809 | 1.31 | 0.85 | | | 1.03 | | 1.42 | | 1.14 | 1.03 | 0.96 | 0.95 | 0.85 | | 1.09 | 0.96 | 0.83 | | 1.04 | 1.29 |
| 1810 | 1.27 | 0.68 | | | 1.03 | | 1.29 | | 0.88 | 0.90 | 0.91 | 0.52 | 0.48 | | 1.07 | 1.03 | 0.61 | | 0.75 | 1.21 |
| 1811 | 1.16 | 0.68 | | | 1.03 | | 1.26 | | 0.73 | 0.82 | 0.80 | 0.66 | 0.63 | | 1.08 | 1.03 | 0.73 | | 0.96 | 1.24 |
| 1812 | 1.26 | 0.76 | | | 1.21 | | 1.44 | | 1.13 | 0.90 | 1.04 | 0.54 | 0.32 | | 1.01 | 0.70 | 0.58 | | 1.06 | 1.17 |
| 1813 | 1.28 | 0.90 | | | 1.04 | | 1.22 | | 1.03 | 0.96 | 0.97 | 0.69 | 0.06 | | 0.85 | 0.55 | 0.35 | | 1.17 | 1.19 |
| 1814 | 1.17 | 1.17 | | | 1.33 | | 1.46 | | 1.32 | 1.22 | 1.20 | 1.15 | 0.67 | | 1.27 | 1.18 | 0.77 | | 1.50 | 1.33 |
| 1815 | 0.92 | 0.85 | | | 0.89 | | 1.05 | | 1.06 | 1.12 | 1.03 | 0.82 | 0.04 | | 0.63 | 0.53 | 0.25 | | 1.20 | 1.19 |
| 1816 | 0.99 | 0.92 | | | 0.82 | | 1.14 | | 1.08 | 1.20 | 1.16 | 0.81 | 0.06 | | 0.94 | 0.84 | 0.55 | | 1.11 | 1.20 |
| 1817 | 1.30 | 1.14 | | | 0.90 | | 1.11 | | 0.95 | 1.03 | 1.09 | 0.89 | 0.25 | | 0.98 | 0.87 | 1.05 | | 1.12 | 0.92 |
| 1818 | 1.43 | 1.14 | | | 1.20 | | 1.05 | | 0.94 | 0.97 | 0.93 | 0.97 | 0.56 | | 0.59 | 0.62 | 0.81 | 0.62 | 0.97 | 0.83 |
| 1819 | 1.31 | 1.12 | | | 0.93 | | 0.86 | | 1.05 | 1.08 | 1.07 | 1.27 | 0.50 | | 0.89 | 0.97 | 0.77 | 0.68 | 1.30 | 1.12 |
| 1820 | 1.33 | 1.18 | | | 0.72 | | 1.05 | | 1.17 | 1.12 | 0.95 | 1.20 | 0.56 | | 0.86 | 1.13 | 1.00 | 1.11 | 1.43 | 1.14 |
| 1821 | 1.21 | 0.93 | | | 0.76 | | 1.00 | | 0.99 | 0.95 | 1.01 | 0.77 | 0.78 | | 1.06 | 1.20 | 1.06 | 1.19 | 1.40 | 1.08 |
| 1822 | 1.32 | 1.22 | | | 0.92 | | 0.70 | | 0.81 | 0.91 | 0.98 | 0.94 | 0.96 | | 0.78 | 0.84 | 1.08 | 1.08 | 1.32 | 1.15 |
| 1823 | 0.93 | 1.00 | | | 0.77 | | 0.88 | | 1.14 | 1.30 | 0.97 | 1.02 | 0.76 | | 0.90 | 1.15 | 0.92 | 1.05 | 1.33 | 1.12 |
| 1824 | 0.70 | 0.71 | | | 0.65 | | 0.82 | | 0.97 | 1.09 | 0.78 | 0.72 | 0.94 | | 0.91 | 1.02 | 1.16 | 1.15 | 1.00 | 0.90 |
| 1825 | 0.62 | 0.82 | | | 0.71 | | 0.78 | | 1.07 | 1.29 | 0.82 | 0.91 | 0.80 | | 0.91 | 1.00 | 0.93 | 1.22 | 1.08 | 1.14 |
| 1826 | 0.69 | 0.69 | | | 0.97 | | 1.01 | | 0.74 | 0.90 | 0.54 | 0.55 | 1.03 | | 1.03 | 1.14 | 0.95 | 0.78 | 0.84 | 0.69 |
| 1827 | 0.65 | 0.65 | | | 0.79 | | 0.96 | | 0.64 | 0.76 | 0.66 | 0.48 | 0.71 | | 0.86 | 0.80 | 0.58 | 0.68 | 1.00 | 0.98 |
| 1828 | 0.45 | 0.37 | | | 0.74 | | 0.95 | | 0.73 | 0.85 | 0.54 | 0.19 | 0.99 | | 0.79 | 0.62 | 0.91 | 0.79 | 0.82 | 0.71 |
| 1829 | 0.98 | 0.74 | | | 0.99 | | 0.85 | | 0.85 | 0.83 | 0.98 | 0.76 | 0.91 | | 0.94 | 0.98 | 0.79 | 0.74 | 1.26 | 1.08 |
| 1830 | 0.68 | 0.46 | | | 1.13 | | 1.27 | | 0.75 | 0.69 | 0.76 | 0.31 | 1.01 | | 1.02 | 1.04 | 1.11 | 0.88 | 0.90 | 0.86 |
| 1831 | 1.07 | 1.41 | 0.61 | | 0.93 | | 1.04 | | 1.26 | 1.10 | 1.34 | 0.94 | 0.94 | | 1.15 | 1.09 | 1.08 | 1.07 | 1.69 | 1.39 |
| 1832 | 1.03 | 1.38 | 0.53 | | 1.13 | | 1.33 | | 1.24 | 1.02 | 1.13 | 1.10 | 0.68 | | 0.94 | 0.80 | 0.79 | 1.06 | 1.43 | 1.10 |
| 1833 | 1.00 | 1.44 | 0.74 | | 1.11 | | 1.26 | | 1.38 | 1.22 | 1.33 | 1.29 | 0.78 | | 1.08 | 0.94 | 0.93 | 1.21 | 1.74 | 1.61 |
| 1834 | 1.20 | 1.52 | 0.69 | | 1.21 | | 1.26 | | 1.32 | 1.06 | 1.26 | 1.12 | 0.59 | | 1.09 | 0.98 | 1.03 | 1.28 | 1.37 | 1.17 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1835 | 1.28 | 1.17 | 0.67 |  | 1.22 |  | 1.22 |  | 1.28 | 1.03 | 1.24 | 1.09 | 0.35 |  | 0.95 | 0.71 | 1.35 | 1.03 | 1.46 | 1.30 |
| 1836 | 1.27 | 1.15 | 1.04 |  | 1.24 |  | 1.43 |  | 0.99 | 0.75 | 1.01 | 0.98 | 0.74 |  | 0.95 | 0.84 | 1.26 | 0.82 | 1.06 | 0.57 |
| 1837 | 1.12 | 0.88 | 1.02 |  | 1.24 |  | 1.79 |  | 1.26 | 0.94 | 1.07 | 0.72 | 0.74 |  | 1.27 | 1.07 | 1.36 | 1.24 | 1.17 | 0.74 |
| 1838 | 1.13 | 1.01 | 0.52 |  | 0.99 |  | 1.26 |  | 1.47 | 1.05 | 1.16 | 0.95 | 0.40 |  | 0.97 | 0.67 | 0.89 | 1.23 | 1.34 | 1.07 |
| 1839 | 0.90 | 0.81 | 0.62 |  | 0.90 | 0.63 | 1.15 |  | 1.16 | 0.66 | 0.84 | 0.49 | 0.32 |  | 0.63 | 0.44 | 0.78 | 1.32 | 1.15 | 0.78 |
| 1840 | 0.85 | 0.50 | 0.43 |  | 0.90 | 0.55 | 1.00 |  | 1.13 | 0.64 | 1.08 | 0.95 | 0.48 | 0.50 | 0.57 | 0.43 | 0.76 | 0.96 | 1.49 | 0.99 |
| 1841 | 1.03 | 0.51 | 0.69 |  | 0.94 | 0.61 | 1.21 |  | 0.79 | 0.59 | 0.83 | 0.51 | 0.71 | 0.49 | 0.84 | 0.72 | 0.81 | 1.18 | 0.80 | 0.45 |
| 1842 | 1.10 | 0.89 | 1.06 |  | 1.23 | 1.11 | 1.06 |  | 1.05 | 0.97 | 1.01 | 1.22 | 1.41 | 1.13 | 1.19 | 1.27 | 1.41 | 1.21 | 1.26 | 0.97 |
| 1843 | 1.15 | 1.21 | 1.08 |  | 1.17 | 0.96 | 1.39 |  | 1.24 | 0.98 | 1.50 | 1.38 | 1.24 | 0.45 | 1.14 | 1.12 | 1.57 | 1.38 | 1.88 | 1.02 |
| 1844 | 1.07 | 1.04 | 0.67 |  | 0.89 | 0.54 | 1.26 |  | 1.00 | 0.90 | 1.42 | 1.04 | 0.94 | 0.50 | 1.23 | 1.11 | 1.20 | 1.42 | 1.50 | 0.83 |
| 1845 | 1.26 | 1.20 | 1.24 |  | 1.18 | 1.16 | 1.61 |  | 1.08 | 0.80 | 1.19 | 1.16 | 1.30 | 1.11 | 1.24 | 1.28 | 1.40 | 1.33 | 1.24 | 0.94 |
| 1846 | 0.94 | 1.01 | 1.15 |  | 0.95 | 0.95 | 1.70 |  | 1.02 | 0.89 | 1.16 | 1.16 | 0.90 | 0.62 | 0.63 | 0.67 | 0.84 | 0.76 | 0.98 | 0.83 |
| 1847 | 1.31 | 1.45 | 1.46 |  | 1.17 | 1.32 | 1.38 |  | 1.17 | 1.04 | 0.96 | 1.10 | 1.19 | 1.10 | 0.93 | 1.05 | 1.38 | 1.08 | 1.12 | 1.27 |
| 1848 | 1.00 | 1.05 | 0.85 |  | 0.97 | 0.95 | 1.28 |  | 1.27 | 1.07 | 1.11 | 1.10 | 1.12 | 0.97 | 1.09 | 1.09 | 1.24 | 1.10 | 1.11 | 0.90 |
| 1849 | 0.84 | 0.89 | 0.92 |  | 1.06 | 0.86 | 1.47 |  | 0.73 | 0.67 | 0.67 | 0.50 | 0.77 | 0.54 | 0.78 | 0.83 | 1.00 | 1.13 | 0.49 | 0.43 |
| 1850 | 1.04 | 1.04 | 1.11 | 0.72 | 1.22 | 1.04 | 1.15 |  | 1.10 | 1.01 | 0.99 | 0.86 | 0.83 | 0.81 | 0.85 | 0.91 | 1.10 | 0.85 | 0.85 | 0.77 |
| 1851 | 1.21 | 1.23 | 1.34 | 1.20 | 1.40 | 1.46 | 1.20 |  | 1.27 | 1.08 | 1.03 | 1.24 | 1.06 | 0.69 | 0.91 | 1.03 | 1.19 | 1.06 | 1.18 | 1.10 |
| 1852 | 1.02 | 1.10 | 1.06 | 0.75 | 1.02 | 0.97 | 0.89 |  | 0.79 | 0.83 | 1.02 | 0.84 | 0.65 | 0.70 | 0.72 | 0.77 | 0.80 | 0.67 | 1.09 | 1.13 |
| 1853 | 1.30 | 1.23 | 0.91 | 0.69 | 1.16 | 0.99 | 1.06 |  | 0.71 | 0.54 | 0.75 | 0.48 | 1.04 | 0.92 | 1.11 | 1.00 | 1.37 | 1.10 | 0.72 | 0.72 |
| 1854 | 0.99 | 1.24 | 1.13 | 0.95 | 1.33 | 1.30 | 1.06 |  | 0.85 | 0.98 | 1.10 | 1.00 | 0.81 | 0.88 | 1.16 | 1.09 | 1.14 | 1.01 | 1.26 | 1.12 |
| 1855 | 1.07 | 1.23 | 1.29 | 1.20 | 1.26 | 1.11 | 0.91 |  | 1.26 | 0.95 | 1.07 | 1.12 | 0.79 | 0.81 | 0.84 | 0.83 | 0.88 | 1.09 | 1.36 | 1.14 |
| 1856 | 0.97 | 0.90 | 1.04 | 0.93 | 1.21 | 0.92 | 0.92 |  | 1.16 | 0.92 | 1.22 | 1.08 | 0.62 | 0.86 | 0.72 | 0.81 | 0.60 | 0.85 | 1.14 | 0.97 |
| 1857 | 1.20 | 1.20 | 0.89 | 0.68 | 1.38 | 1.16 | 1.03 |  | 1.14 | 1.04 | 1.16 | 1.33 | 0.72 | 0.68 | 0.88 | 1.12 | 0.60 | 1.05 | 1.12 | 1.09 |
| 1858 | 0.88 | 0.85 | 1.08 | 1.02 | 1.38 | 1.00 | 1.07 |  | 0.94 | 0.90 | 0.83 | 1.06 | 0.07 | 0.56 | 0.38 | 0.55 | 0.39 | 0.76 | 0.92 | 0.77 |
| 1859 | 1.22 | 1.22 | 1.06 | 0.78 | 1.40 | 1.01 | 0.89 |  | 1.03 | 0.79 | 0.74 | 0.94 | 0.87 | 1.12 | 1.10 | 1.24 | 1.01 | 1.20 | 0.75 | 0.60 |
| 1860 | 1.48 | 1.39 | 1.25 | 1.09 | 1.55 | 1.26 | 1.22 |  | 0.98 | 0.67 | 1.17 | 1.13 | 0.30 | 0.65 | 0.68 | 0.61 | 0.42 | 0.62 | 0.97 | 0.81 |
| 1861 | 1.41 | 1.27 | 1.46 | 0.98 | 1.85 | 1.59 | 1.09 |  | 1.07 | 1.00 | 1.12 | 1.39 | 0.89 | 0.83 | 0.78 | 0.91 | 1.03 | 0.89 | 1.04 | 1.10 |
| 1862 | 1.15 | 1.06 | 1.11 | 0.95 | 1.55 | 1.19 | 1.18 |  | 1.03 | 0.75 | 1.07 | 0.92 | 0.60 | 0.79 | 0.90 | 0.88 | 0.69 | 0.56 | 1.02 | 0.79 |
| 1863 | 1.19 | 1.29 | 1.09 | 0.88 | 1.22 | 1.02 | 1.00 |  | 1.04 | 0.87 | 1.00 | 1.11 | 0.97 | 0.85 | 1.14 | 1.17 | 0.92 | 0.84 | 1.09 | 1.05 |
| 1864 | 1.31 | 1.36 | 1.05 | 0.68 | 1.14 | 0.97 | 0.82 |  | 0.89 | 0.91 | 1.12 | 1.42 | 1.18 | 1.20 | 1.31 | 1.41 | 1.23 | 1.04 | 1.52 | 1.26 |
| 1865 | 0.89 | 0.81 | 1.29 | 0.89 | 1.29 | 1.03 | 0.90 |  | 1.02 | 0.86 | 0.94 | 1.10 | 1.23 | 0.97 | 1.39 | 1.27 | 1.08 | 0.98 | 0.97 | 0.82 |
| 1866 | 0.92 | 0.96 | 1.20 | 0.93 | 1.57 | 1.13 | 1.14 |  | 0.67 | 0.56 | 1.02 | 0.87 | 1.25 | 1.06 | 1.54 | 1.32 | 0.91 | 1.02 | 0.81 | 0.76 |
| 1867 | 1.17 | 1.09 | 1.11 | 0.84 | 1.31 | 1.22 | 0.97 |  | 1.15 | 0.77 | 1.01 | 0.89 | 1.48 | 1.12 | 1.56 | 1.34 | 1.02 | 0.95 | 0.98 | 0.76 |
| 1868 | 0.90 | 0.88 | 1.03 | 0.81 | 1.18 | 1.11 | 0.56 |  | 1.10 | 0.88 | 1.00 | 1.16 | 0.88 | 0.88 | 0.87 | 0.78 | 0.60 | 0.71 | 0.85 | 0.81 |
| 1869 | 0.92 | 0.92 | 1.10 | 0.70 | 1.17 | 1.05 | 0.77 |  | 1.12 | 0.79 | 1.01 | 0.96 | 1.31 | 0.82 | 1.35 | 1.21 | 0.97 | 0.82 | 0.67 | 0.58 |
| 1870 | 0.71 | 0.80 | 0.80 | 0.78 | 1.09 | 1.01 | 0.54 |  | 1.14 | 1.14 | 1.24 | 1.86 | 1.42 | 0.75 | 1.09 | 1.23 | 1.00 | 1.03 | 1.21 | 1.33 |
| 1871 | 0.59 | 0.69 | 1.13 | 0.74 | 1.37 | 1.37 | 1.01 |  | 1.02 | 0.83 | 1.02 | 1.33 | 1.43 | 0.81 | 1.30 | 1.42 | 0.98 | 0.87 | 0.75 | 0.85 |
| 1872 | 0.69 | 0.84 | 0.80 | 0.67 | 0.63 | 0.95 | 0.47 |  | 0.91 | 0.85 | 0.80 | 1.13 | 1.09 | 0.46 | 0.74 | 1.04 | 0.78 | 0.67 | 0.55 | 0.77 |
| 1873 | 0.68 | 0.84 | 0.91 | 0.40 | 0.95 | 1.23 | 0.72 |  | 1.16 | 1.14 | 1.42 | 2.00 | 1.76 | 1.01 | 1.35 | 1.75 | 1.40 | 1.27 | 1.54 | 1.59 |
| 1874 | 0.61 | 0.69 | 0.98 | 0.68 | 0.71 | 1.02 | 0.58 |  | 1.03 | 0.89 | 0.90 | 1.16 | 1.26 | 0.89 | 1.09 | 1.19 | 1.18 | 1.01 | 0.82 | 0.94 |
| 1875 | 0.59 | 0.61 | 0.98 | 1.07 | 1.01 | 1.21 | 0.60 |  | 0.80 | 0.77 | 0.78 | 1.05 | 1.06 | 0.93 | 0.74 | 0.99 | 0.83 | 1.01 | 0.57 | 0.87 |
| 1876 | 0.96 | 0.96 | 1.08 | 1.01 | 1.26 | 1.36 | 1.00 |  | 0.83 | 0.82 | 0.88 | 1.18 | 1.36 | 0.96 | 1.03 | 1.16 | 1.15 | 1.07 | 0.50 | 0.79 |
| 1877 | 0.88 | 0.97 | 0.58 | 0.51 | 0.77 | 0.92 | 0.48 |  | 0.70 | 0.74 | 0.86 | 1.24 | 1.07 | 0.68 | 0.83 | 1.00 | 0.81 | 0.93 | 1.02 | 1.13 |
| 1878 | 0.74 | 0.95 | 0.70 | 0.62 | 1.03 | 1.13 | 0.62 |  | 0.70 | 0.77 | 0.77 | 0.97 | 1.11 | 0.54 | 0.81 | 0.86 | 0.53 | 0.73 | 0.63 | 0.68 |
| 1879 | 0.98 | 1.10 | 1.18 | 1.04 | 1.18 | 1.04 | 0.97 |  | 0.65 | 0.61 | 0.92 | 1.01 | 1.27 | 0.86 | 0.91 | 1.26 | 0.82 | 1.01 | 0.71 | 0.79 |
| 1880 | 1.19 | 1.03 | 1.38 | 1.11 | 1.36 | 1.31 | 1.11 |  | 0.55 | 0.59 | 0.90 | 0.95 | 1.07 | 0.74 | 0.89 | 1.14 | 0.98 | 1.07 | 0.47 | 0.65 |
| 1881 | 0.89 | 1.07 | 1.08 | 0.96 | 1.41 | 1.41 | 1.19 | 0.84 | 0.41 | 0.34 | 0.67 | 0.34 | 0.86 | 0.60 | 0.87 | 1.07 | 0.68 | 0.99 | 0.21 | 0.25 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1882 | 0.73 | 0.66 | 1.10 | 1.03 | 1.04 | 1.01 | 0.91 | 1.03 | 0.84 | 0.93 | 1.03 | 0.92 | 1.41 | 0.95 | 1.06 | 1.20 | 1.16 | 1.16 | 0.75 | 0.69 |
| 1883 | 1.06 | 1.02 | 0.96 | 0.93 | 1.24 | 1.12 | 0.84 | 1.23 | 0.89 | 0.97 | 1.12 | 1.09 | 1.87 | 1.10 | 1.14 | 1.25 | 1.33 | 1.29 | 1.02 | 0.99 |
| 1884 | 1.03 | 1.09 | 0.75 | 0.79 | 1.07 | 1.14 | 0.72 | 0.91 | 0.72 | 0.87 | 0.77 | 0.69 | 1.32 | 0.77 | 1.16 | 1.39 | 0.97 | 1.12 | 0.57 | 0.55 |
| 1885 | 0.88 | 1.07 | 0.60 | 0.55 | 0.85 | 0.94 | 0.43 | 0.63 | 1.05 | 1.34 | 0.91 | 0.87 | 1.21 | 0.52 | 0.77 | 1.04 | 0.86 | 0.92 | 0.76 | 0.78 |
| 1886 | 0.96 | 0.95 | 0.74 | 0.57 | 0.90 | 0.93 | 0.71 | 0.53 | 1.29 | 1.17 | 1.07 | 1.06 | 1.51 | 0.92 | 0.91 | 1.27 | 1.25 | 1.10 | 0.91 | 0.92 |
| 1887 | 0.63 | 0.68 | 0.51 | 0.47 | 0.78 | 0.86 | 0.57 | 0.40 | 1.10 | 0.97 | 1.05 | 1.04 | 0.51 | 0.38 | 0.25 | 0.32 | 0.40 | 0.45 | 0.99 | 0.81 |
| 1888 | 0.87 | 0.95 | 0.71 | 0.65 | 0.94 | 0.93 | 0.72 | 0.77 | 1.26 | 1.05 | 1.18 | 1.15 | 0.61 | 0.74 | 0.43 | 0.53 | 0.60 | 0.70 | 1.12 | 0.99 |
| 1889 | 0.75 | 0.79 | 0.83 | 0.74 | 1.05 | 1.08 | 0.79 | 0.83 | 1.19 | 0.98 | 1.13 | 1.02 | 1.25 | 1.12 | 0.75 | 0.82 | 0.66 | 0.78 | 0.97 | 1.01 |
| 1890 | 1.15 | 1.07 | 1.09 | 0.95 | 1.14 | 1.07 | 1.21 | 1.18 | 0.77 | 0.73 | 0.81 | 0.95 | 1.08 | 1.07 | 0.86 | 0.97 | 0.91 | 0.91 | 0.81 | 1.05 |
| 1891 | 0.83 | 0.73 | 0.69 | 0.71 | 0.73 | 0.66 | 0.75 | 0.67 | 0.96 | 0.71 | 0.76 | 0.58 | 1.11 | 1.10 | 1.02 | 0.94 | 0.98 | 0.98 | 0.71 | 0.65 |
| 1892 | 0.87 | 0.96 | 0.67 | 0.67 | 0.76 | 0.69 | 0.63 | 0.60 | 0.77 | 0.73 | 0.83 | 0.70 | 1.23 | 0.98 | 0.93 | 0.83 | 0.91 | 0.78 | 0.77 | 0.73 |
| 1893 | 0.86 | 0.81 | 0.90 | 0.86 | 0.63 | 0.58 | 0.77 | 0.79 | 0.85 | 0.78 | 0.95 | 0.98 | 1.03 | 0.81 | 0.88 | 0.95 | 0.99 | 0.84 | 1.09 | 1.08 |
| 1894 | 0.83 | 0.79 | 0.66 | 0.66 | 0.57 | 0.39 | 0.97 | 0.85 | 0.68 | 0.65 | 0.84 | 0.93 | 1.09 | 0.99 | 1.04 | 0.95 | 0.87 | 0.77 | 0.77 | 0.87 |
| 1895 | 0.77 | 0.71 | 0.70 | 0.55 | 0.42 | 0.18 | 0.83 | 0.67 | 0.81 | 0.74 | 0.89 | 0.71 | 1.31 | 1.17 | 0.78 | 0.53 | 0.93 | 1.01 | 1.01 | 0.77 |
| 1896 | 1.44 | 1.10 | 1.06 | 0.92 | 1.03 | 0.67 | 1.04 | 0.90 | 0.74 | 0.57 | 0.74 | 0.53 | 1.53 | 1.33 | 0.97 | 0.80 | 1.17 | 0.99 | 0.74 | 0.63 |
| 1897 | 0.94 | 0.57 | 0.13 | 0.25 | 0.36 | 0.00 | 0.37 | 0.38 | 0.92 | 0.72 | 0.78 | 0.48 | 1.32 | 1.27 | 1.02 | 0.58 | 1.03 | 0.91 | 1.20 | 0.80 |
| 1898 | 1.04 | 0.80 | 0.52 | 0.60 | 0.65 | 0.44 | 0.80 | 0.80 | 0.71 | 0.72 | 0.70 | 0.39 | 1.41 | 1.30 | 0.98 | 0.60 | 1.10 | 0.94 | 0.84 | 0.71 |
| 1899 | 0.87 | 0.97 | 1.28 | 1.13 | 0.99 | 0.94 | 1.38 | 1.35 | 1.17 | 1.09 | 1.27 | 1.37 | 1.48 | 1.39 | 1.08 | 1.01 | 1.21 | 1.15 | 1.36 | 1.34 |
| 1900 | 1.53 | 1.59 | 0.77 | 0.79 | 0.71 | 0.64 | 0.84 | 0.92 | 1.00 | 0.93 | 0.90 | 0.92 | 1.13 | 1.03 | 0.96 | 0.76 | 0.86 | 0.94 | 1.18 | 1.12 |
| 1901 | 1.26 | 1.36 | 0.74 | 0.85 | 0.65 | 0.65 | 0.87 | 1.06 | 0.72 | 0.82 | 0.69 | 0.72 | 1.06 | 1.12 | 0.90 | 0.75 | 0.66 | 0.90 | 0.79 | 1.07 |
| 1902 | 1.14 | 1.18 | 0.88 | 0.93 | 0.71 | 0.68 | 0.86 | 0.84 | 0.91 | 1.07 | 1.04 | 1.16 | 1.52 | 1.29 | 1.28 | 1.23 | 1.16 | 1.17 | 1.10 | 1.22 |
| 1903 | 1.26 | 1.35 | 0.65 | 0.89 | 0.64 | 0.74 | 0.71 | 1.04 | 0.68 | 0.82 | 0.55 | 0.57 | 1.18 | 1.02 | 0.90 | 0.82 | 0.75 | 1.08 | 0.50 | 0.69 |
| 1904 | 1.43 | 1.53 | 1.24 | 1.13 | 0.92 | 0.97 | 1.01 | 1.17 | 0.77 | 1.00 | 0.83 | 1.26 | 1.52 | 1.16 | 0.97 | 1.33 | 1.33 | 1.23 | 0.91 | 1.35 |
| 1905 | 1.05 | 1.14 | 0.92 | 0.94 | 0.67 | 0.91 | 0.87 | 0.97 | 0.92 | 0.90 | 0.69 | 0.59 | 1.23 | 0.88 | 0.74 | 0.59 | 0.74 | 0.90 | 0.64 | 0.74 |
| 1906 | 1.36 | 1.38 | 1.20 | 1.26 | 1.04 | 1.28 | 1.08 | 1.17 | 1.24 | 1.23 | 1.13 | 1.18 | 1.56 | 1.20 | 0.75 | 0.73 | 1.02 | 1.10 | 1.17 | 1.32 |
| 1907 | 1.13 | 1.04 | 0.63 | 0.68 | 0.74 | 0.99 | 0.75 | 0.64 | 1.11 | 1.04 | 1.12 | 1.15 | 1.39 | 0.80 | 0.93 | 0.70 | 0.97 | 0.91 | 1.35 | 1.30 |
| 1908 | 0.79 | 0.97 | 0.75 | 0.77 | 0.76 | 0.94 | 0.67 | 0.64 | 0.91 | 0.94 | 0.86 | 0.90 | 0.95 | 0.49 | 0.58 | 0.65 | 0.56 | 0.89 | 0.99 | 1.06 |
| 1909 | 0.81 | 1.06 | 0.63 | 0.81 | 0.90 | 0.92 | 0.88 | 0.81 | 0.96 | 0.84 | 1.05 | 1.11 | 1.26 | 0.98 | 0.95 | 0.97 | 0.87 | 1.04 | 0.96 | 1.09 |
| 1910 | 0.72 | 0.90 | 1.04 | 1.13 | 1.18 | 1.03 | 1.09 | 1.05 | 1.10 | 0.86 | 1.03 | 1.03 | 1.49 | 0.97 | 1.15 | 1.07 | 0.97 | 0.94 | 0.95 | 0.95 |
| 1911 | 1.06 | 1.09 | 0.46 | 0.83 | 0.73 | 0.71 | 0.69 | 0.72 | 0.56 | 0.61 | 0.78 | 0.64 | 1.07 | 0.86 | 0.89 | 0.87 | 0.73 | 0.78 | 0.68 | 0.85 |
| 1912 | 1.26 | 1.29 | 0.88 | 1.12 | 0.76 | 0.91 | 0.89 | 0.82 | 1.27 | 0.97 | 1.15 | 0.93 | 1.12 | 1.01 | 0.95 | 1.07 | 0.75 | 0.78 | 1.05 | 1.03 |
| 1913 | 1.17 | 1.46 | 0.47 | 0.81 | 0.76 | 0.89 | 0.82 | 0.96 | 1.13 | 1.09 | 1.19 | 1.24 | 1.29 | 1.28 | 1.36 | 1.46 | 0.99 | 1.09 | 1.00 | 1.25 |
| 1914 | 0.90 | 1.22 | 0.37 | 0.77 | 0.26 | 0.38 | 0.56 | 0.83 | 0.88 | 0.91 | 0.68 | 0.59 | 1.25 | 1.19 | 1.31 | 1.32 | 0.96 | 1.03 | 0.48 | 0.75 |
| 1915 | 1.05 | 1.22 | 0.47 | 0.67 | 0.01 | 0.19 | 0.46 | 0.84 | 1.16 | 0.92 | 0.68 | 0.49 | 1.29 | 1.04 | 1.24 | 1.15 | 0.87 | 0.87 | 0.48 | 0.60 |
| 1916 | 0.45 | 0.65 | 0.68 | 0.83 | 0.00 | 0.02 | 0.40 | 0.72 | 1.27 | 1.09 | 0.88 | 1.04 | 1.31 | 1.15 | 1.23 | 1.10 | 0.86 | 0.96 | 0.85 | 1.04 |
| 1917 | 0.56 | 0.45 | 0.60 | 0.74 | 0.04 | 0.00 | 0.51 | 0.85 | 1.15 | 1.05 | 0.94 | 1.05 | 1.73 | 1.51 | 1.60 | 1.59 | 1.37 | 1.25 | 0.89 | 1.03 |
| 1918 | 0.39 | 0.44 | 0.42 | 0.62 | 0.28 | 0.08 | 0.27 | 0.61 | 0.46 | 0.65 | 0.81 | 1.02 | 1.01 | 1.14 | 0.85 | 0.95 | 0.79 | 0.95 | 0.90 | 1.23 |
| 1919 | 0.98 | 0.77 | 0.31 | 0.70 | 0.00 | 0.00 | 0.06 | 0.45 | 0.88 | 0.88 | 0.77 | 0.80 | 0.99 | 1.13 | 1.08 | 1.07 | 0.84 | 1.04 | 0.66 | 0.80 |
| 1920 | 1.12 | 0.52 | 0.53 | 0.82 | 0.00 | 0.00 | 0.12 | 0.29 | 0.95 | 1.02 | 0.42 | 0.46 | 1.23 | 1.19 | 1.23 | 1.38 | 1.06 | 1.12 | 0.42 | 0.69 |
| 1921 | 0.98 | 0.68 | 0.78 | 1.02 | 0.27 | 0.18 | 0.39 | 0.70 | 1.17 | 1.18 | 0.62 | 0.63 | 0.53 | 0.69 | 0.75 | 0.82 | 0.88 | 0.81 | 0.49 | 0.78 |
| 1922 | 1.19 | 1.07 | 0.89 | 1.04 | 0.94 | 0.77 | 0.91 | 1.05 | 0.80 | 0.76 | 0.93 | 1.11 | 1.36 | 1.27 | 1.16 | 1.32 | 1.40 | 1.21 | 0.83 | 1.03 |
| 1923 | 1.08 | 1.11 | 0.63 | 0.85 | 0.68 | 0.67 | 0.70 | 0.88 | 1.06 | 1.09 | 0.96 | 1.35 | 1.01 | 1.21 | 1.11 | 1.30 | 1.09 | 1.32 | 1.09 | 1.40 |
| 1924 | 1.19 | 1.19 | 0.92 | 1.12 | 0.80 | 0.91 | 1.13 | 1.20 | 1.18 | 1.06 | 0.56 | 0.72 | 1.16 | 1.26 | 1.29 | 1.46 | 1.12 | 1.17 | 0.52 | 0.78 |
| 1925 | 1.26 | 1.32 | 0.78 | 0.79 | 0.89 | 0.94 | 1.11 | 1.28 | 1.08 | 0.99 | 0.78 | 0.91 | 1.21 | 1.32 | 0.88 | 1.21 | 1.30 | 1.41 | 0.67 | 1.06 |
| 1926 | 1.33 | 1.27 | 0.65 | 0.79 | 0.85 | 0.98 | 1.22 | 1.25 | 1.25 | 1.38 | 0.82 | 1.08 | 0.88 | 1.04 | 0.94 | 1.00 | 1.05 | 1.13 | 1.00 | 1.17 |
| 1927 | 1.18 | 1.08 | 0.77 | 0.78 | 1.05 | 0.98 | 1.15 | 0.96 | 1.07 | 1.24 | 0.78 | 0.87 | 0.84 | 0.93 | 0.71 | 0.88 | 1.07 | 0.97 | 0.86 | 1.17 |
| 1928 | 1.17 | 1.18 | 0.91 | 0.82 | 1.16 | 1.09 | 1.17 | 1.12 | 1.01 | 0.96 | 0.85 | 0.85 | 0.98 | 0.96 | 1.16 | 1.26 | 1.19 | 1.00 | 0.99 | 1.14 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1929 | 1.05 | 1.14 | 0.71 | 0.70 | 0.97 | 1.01 | 1.11 | 1.01 | 1.11 | 1.15 | 0.92 | 1.13 | 0.76 | 0.82 | 0.83 | 1.04 | 0.89 | 1.00 | 1.01 | 1.21 |
| 1930 | 1.16 | 1.17 | 0.80 | 0.86 | 1.02 | 1.00 | 1.18 | 1.09 | 0.87 | 0.90 | 1.01 | 1.05 | 1.06 | 0.94 | 0.95 | 1.13 | 1.11 | 1.01 | 0.97 | 1.09 |
| 1931 | 1.33 | 1.13 | 0.85 | 0.82 | 1.18 | 1.09 | 1.22 | 1.05 | 0.72 | 0.65 | 1.00 | 0.83 | 1.27 | 1.02 | 1.24 | 1.39 | 1.25 | 1.20 | 0.83 | 0.87 |
| 1932 | 1.52 | 1.37 | 1.07 | 0.96 | 1.20 | 1.23 | 1.17 | 0.90 | 1.17 | 0.94 | 0.76 | 0.65 | 0.90 | 0.75 | 0.73 | 1.01 | 1.01 | 0.94 | 0.71 | 0.64 |
| 1933 | 1.79 | 1.61 | 1.22 | 1.14 | 1.35 | 1.28 | 1.27 | 1.00 | 0.98 | 0.94 | 1.43 | 1.40 | 1.00 | 0.81 | 0.89 | 1.03 | 1.30 | 1.00 | 1.46 | 1.23 |
| 1934 | 1.31 | 1.33 | 1.05 | 0.93 | 1.30 | 1.23 | 1.01 | 0.85 | 0.78 | 0.64 | 0.78 | 0.53 | 1.35 | 1.22 | 0.99 | 1.24 | 1.71 | 1.31 | 0.54 | 0.56 |
| 1935 | 1.23 | 1.13 | 1.16 | 1.15 | 1.12 | 1.13 | 1.05 | 0.94 | 1.07 | 0.98 | 1.11 | 0.96 | 0.88 | 0.77 | 0.70 | 0.85 | 0.94 | 0.90 | 0.92 | 0.92 |
| 1936 | 0.97 | 0.97 | 1.19 | 1.23 | 0.92 | 0.96 | 1.03 | 0.94 | 1.36 | 1.24 | 1.33 | 1.37 | 1.18 | 0.98 | 1.14 | 1.28 | 1.22 | 1.01 | 1.29 | 1.25 |
| 1937 | 0.93 | 0.96 | 0.91 | 1.03 | 0.63 | 0.69 | 0.87 | 0.63 | 1.23 | 1.29 | 1.36 | 1.12 | 1.03 | 0.86 | 0.97 | 1.06 | 0.99 | 1.02 | 1.07 | 0.96 |
| 1938 | 0.67 | 0.78 | 0.67 | 0.82 | 1.07 | 1.02 | 1.01 | 0.77 | 1.11 | 1.05 | 1.18 | 1.12 | 0.97 | 0.94 | 0.77 | 0.71 | 0.90 | 0.94 | 1.01 | 1.03 |
| 1939 | 0.81 | 0.90 | 1.25 | 1.30 | 1.27 | 1.41 | 1.12 | 0.93 | 1.23 | 1.18 | 1.09 | 1.54 | 1.32 | 1.37 | 0.90 | 0.96 | 1.12 | 1.14 | 0.97 | 1.12 |
| 1940 | 0.48 | 0.75 | 0.68 | 0.77 | 0.86 | 1.14 | 1.00 | 0.78 | 0.76 | 0.82 | 1.02 | 1.71 | 1.03 | 1.18 | 0.74 | 0.59 | 0.92 | 1.05 | 1.23 | 1.33 |
| 1941 | 1.07 | 1.17 | 0.71 | 0.80 | 0.73 | 1.01 | 0.81 | 0.53 | 1.15 | 1.24 | 0.98 | 1.55 | 0.53 | 0.92 | 0.37 | -0.04 | 0.48 | 0.75 | 1.10 | 1.11 |
| 1942 | 1.07 | 1.05 | 0.69 | 0.67 | 0.79 | 0.89 | 0.56 | 0.32 | 1.20 | 1.16 | 1.03 | 1.42 | 0.75 | 0.90 | 0.84 | 0.40 | 0.80 | 0.86 | 1.05 | 1.15 |
| 1943 | 0.50 | 0.81 | 0.48 | 0.55 | 0.95 | 0.93 | 0.65 | 0.54 | 0.67 | 0.87 | 1.08 | 1.76 | 0.57 | 0.76 | 0.69 | 0.64 | 0.58 | 0.90 | 0.94 | 1.19 |
| 1944 | 0.91 | 0.90 | 0.64 | 0.63 | 0.86 | 0.74 | 0.86 | 0.62 | 1.39 | 1.17 | 1.05 | 1.33 | 1.00 | 1.09 | 1.23 | 1.10 | 1.05 | 1.20 | 1.02 | 1.02 |
| 1945 | 0.62 | 0.63 | 0.79 | 0.83 | 0.72 | 0.75 | 0.75 | 0.64 | 1.22 | 1.13 | 0.89 | 1.29 | 0.85 | 1.02 | 1.06 | 0.91 | 1.18 | 1.15 | 0.89 | 1.03 |
| 1946 | 1.02 | 1.08 | 0.85 | 0.80 | 0.82 | 0.88 | 0.80 | 0.79 | 1.11 | 1.19 | 1.20 | 1.85 | 0.93 | 0.88 | 1.05 | 0.87 | 1.24 | 1.13 | 1.29 | 1.37 |
| 1947 | 0.85 | 0.91 | 0.82 | 0.87 | 0.78 | 0.76 | 0.82 | 0.69 | 1.31 | 1.10 | 1.06 | 1.10 | 0.87 | 0.76 | 1.16 | 0.85 | 1.11 | 1.05 | 1.29 | 1.13 |
| 1948 | 0.78 | 0.85 | 0.86 | 0.89 | 0.77 | 0.60 | 1.02 | 0.90 | 1.39 | 1.33 | 1.27 | 1.53 | 0.88 | 0.88 | 1.08 | 0.61 | 1.27 | 1.21 | 1.44 | 1.30 |
| 1949 | 0.61 | 0.51 | 0.60 | 0.77 | 0.57 | 0.33 | 0.84 | 0.64 | 1.34 | 1.27 | 1.30 | 1.26 | 0.83 | 0.92 | 1.01 | 0.56 | 1.11 | 1.18 | 1.13 | 1.05 |
| 1950 | 0.92 | 0.81 | 0.71 | 0.71 | 1.13 | 0.87 | 0.96 | 0.93 | 0.79 | 1.11 | 1.28 | 1.30 | 0.94 | 0.95 | 0.71 | 0.71 | 1.14 | 1.09 | 1.00 | 1.05 |
| 1951 | 1.19 | 1.11 | 0.87 | 0.85 | 0.84 | 0.77 | 0.94 | 0.90 | 1.31 | 1.15 | 1.06 | 1.17 | 1.10 | 1.03 | 0.93 | 0.97 | 1.24 | 1.06 | 1.08 | 0.96 |
| 1952 | 0.79 | 0.71 | 0.70 | 0.71 | 0.75 | 0.55 | 0.82 | 0.67 | 1.27 | 1.15 | 1.05 | 1.31 | 0.86 | 0.79 | 0.89 | 0.56 | 0.88 | 0.84 | 1.06 | 0.92 |
| 1953 | 1.09 | 1.03 | 0.85 | 0.89 | 1.07 | 0.90 | 1.01 | 0.95 | 1.21 | 1.20 | 1.07 | 1.13 | 0.87 | 0.97 | 1.05 | 0.91 | 0.94 | 0.85 | 1.02 | 1.03 |
| 1954 | 0.39 | 0.40 | 0.70 | 0.76 | 0.98 | 0.85 | 0.94 | 0.94 | 0.69 | 0.99 | 0.83 | 1.16 | 0.47 | 0.60 | 0.57 | 0.67 | 0.51 | 0.57 | 0.64 | 0.92 |
| 1955 | 0.99 | 0.90 | 0.81 | 0.75 | 1.08 | 0.89 | 0.85 | 0.79 | 0.79 | 1.10 | 1.09 | 1.13 | 1.13 | 1.11 | 1.21 | 1.13 | 1.13 | 1.10 | 0.77 | 0.92 |
| 1956 | 0.96 | 0.88 | 0.76 | 0.73 | 0.83 | 0.66 | 0.63 | 0.54 | 1.00 | 1.08 | 1.45 | 1.96 | 1.19 | 1.12 | 1.00 | 1.17 | 1.16 | 0.94 | 1.21 | 1.35 |
| 1957 | 0.56 | 0.46 | 0.65 | 0.81 | 0.87 | 0.70 | 0.77 | 0.84 | 1.14 | 1.37 | 0.89 | 1.18 | 1.01 | 1.07 | 1.02 | 0.92 | 0.98 | 1.00 | 0.86 | 0.92 |
| 1958 | 0.85 | 0.76 | 0.99 | 1.18 | 1.02 | 0.88 | 0.96 | 0.98 | 1.47 | 1.53 | 1.20 | 1.39 | 1.31 | 1.23 | 1.34 | 1.04 | 1.15 | 1.09 | 1.07 | 1.04 |
| 1959 | 0.87 | 0.87 | 0.95 | 1.19 | 1.24 | 1.09 | 1.12 | 1.25 | 0.87 | 1.25 | 1.08 | 1.36 | 1.10 | 1.09 | 1.34 | 0.91 | 1.08 | 1.06 | 0.80 | 0.93 |
| 1960 | 0.79 | 0.84 | 0.96 | 1.20 | 1.22 | 1.07 | 1.12 | 1.25 | 1.30 | 1.70 | 1.51 | 1.63 | 1.08 | 0.99 | 1.36 | 0.77 | 0.89 | 0.88 | 0.98 | 1.00 |
| 1961 | 0.77 | 0.61 | 0.93 | 1.03 | 1.26 | 1.09 | 1.15 | 1.16 | 1.03 | 1.38 | 1.38 | 1.64 | 1.30 | 1.06 | 1.30 | 0.65 | 1.07 | 1.02 | 1.09 | 1.13 |
| 1962 | 0.64 | 0.59 | 1.00 | 0.93 | 1.24 | 1.13 | 1.13 | 1.24 | 1.15 | 1.35 | 1.26 | 1.63 | 1.39 | 1.09 | 1.39 | 0.73 | 1.18 | 1.07 | 1.07 | 1.13 |
| 1963 | 1.04 | 1.01 | 0.88 | 0.85 | 1.21 | 1.19 | 1.10 | 1.04 | 0.69 | 0.89 | 0.92 | 1.22 | 1.06 | 0.95 | 1.19 | 0.87 | 1.06 | 0.90 | 0.61 | 0.75 |
| 1964 | 0.91 | 0.86 | 0.88 | 0.67 | 0.90 | 0.91 | 0.78 | 0.73 | 0.99 | 1.10 | 1.29 | 1.72 | 1.16 | 1.08 | 1.27 | 1.13 | 1.22 | 1.00 | 1.40 | 1.25 |
| 1965 | 1.21 | 1.03 | 0.77 | 0.97 | 0.95 | 0.95 | 0.78 | 0.90 | 1.34 | 1.38 | 1.39 | 1.06 | 0.94 | 0.92 | 1.22 | 0.70 | 0.98 | 0.94 | 1.13 | 0.93 |
| 1966 | 0.92 | 0.97 | 0.87 | 1.10 | 1.28 | 1.32 | 1.27 | 1.27 | 0.61 | 1.08 | 1.83 | 1.47 | 1.02 | 1.07 | 1.52 | 1.11 | 1.08 | 0.99 | 1.14 | 1.01 |
| 1967 | 1.12 | 1.25 | 0.71 | 0.81 | 1.15 | 1.18 | 0.86 | 0.83 | 0.54 | 0.90 | 1.49 | 1.40 | 1.04 | 1.14 | 0.88 | 1.10 | 1.19 | 1.07 | 1.14 | 1.18 |
| 1968 | 1.24 | 1.46 | 1.21 | 1.33 | 1.08 | 1.17 | 0.94 | 0.91 | 1.40 | 1.34 | 1.41 | 1.34 | 1.25 | 1.30 | 1.46 | 1.33 | 1.30 | 1.15 | 1.34 | 1.22 |
| 1969 | 1.08 | 1.39 | 0.95 | 1.11 | 1.08 | 1.14 | 1.03 | 1.02 | 1.22 | 1.26 | 1.29 | 1.20 | 0.83 | 1.20 | 1.11 | 1.09 | 0.99 | 1.11 | 1.65 | 1.30 |
| 1970 | 1.31 | 1.32 | 0.96 | 1.12 | 1.03 | 1.01 | 0.91 | 0.89 | 0.86 | 1.06 | 1.09 | 0.91 | 1.33 | 1.57 | 1.42 | 1.62 | 1.38 | 1.36 | 1.30 | 1.06 |
| 1971 | 1.34 | 1.57 | 0.63 | 0.62 | 1.24 | 1.33 | 0.93 | 0.97 | 0.52 | 0.75 | 0.86 | 0.96 | 1.42 | 1.50 | 1.25 | 1.72 | 1.53 | 1.29 | 0.67 | 0.77 |
| 1972 | 0.82 | 1.17 | 1.03 | 1.19 | 1.37 | 1.50 | 1.06 | 0.95 | 1.22 | 1.53 | 1.10 | 0.83 | 1.13 | 1.27 | 1.64 | 1.58 | 1.08 | 0.91 | 0.89 | 0.71 |
| 1973 | 1.32 | 1.68 | 1.55 | 1.57 | 1.06 | 1.21 | 1.04 | 0.75 | 1.05 | 1.37 | 0.81 | 0.66 | 1.09 | 1.24 | 1.29 | 1.52 | 1.13 | 1.11 | 1.08 | 0.91 |
| 1974 | 0.92 | 1.30 | 1.05 | 1.09 | 1.17 | 1.28 | 0.97 | 0.80 | 1.00 | 1.20 | 1.24 | 1.26 | 1.12 | 1.32 | 1.17 | 1.49 | 1.20 | 1.07 | 1.43 | 1.45 |
| 1975 | 0.74 | 1.41 | 1.26 | 1.54 | 0.67 | 1.03 | 0.85 | 0.58 | 0.95 | 1.29 | 0.96 | 0.68 | 1.17 | 1.43 | 1.43 | 1.63 | 1.32 | 1.28 | 0.76 | 0.98 |

Appendix A - Corrected Index Tree-Ring Chronologies.

| YEAR | FRCDF | FRCWF | FNLDF | FNLWF | PEWDF | PEWWF | LGRDF | LGRWF | SRRDF | SRRWF | BONDF | BONWF | POLDF | POLWF | ALADF | ALAWF | LAJDF | LAJWF | RTCDF | RTCWF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1976 | 0.80 | 1.48 | 0.65 | 0.97 | 1.04 | 1.36 | 0.98 | 1.00 | 1.10 | 1.36 | 1.03 | 1.11 | 0.91 | 1.25 | 1.06 | 1.34 | 1.11 | 1.06 | 0.94 | 1.08 |
| 1977 | 1.15 | 1.52 | 0.87 | 0.97 | 1.12 | 1.50 | 1.12 | 1.14 | 0.63 | 1.13 | 1.06 | 0.95 | 0.88 | 1.11 | 1.16 | 1.35 | 0.96 | 0.99 | 0.74 | 0.92 |
| 1978 | 0.78 | 1.02 | 0.84 | 0.89 | 0.92 | 1.26 | 0.92 | 1.16 | 1.07 | 1.21 | 0.95 | 0.72 | 1.00 | 1.14 | 1.00 | 1.28 | 1.11 | 1.11 | 0.89 | 0.85 |
| 1979 | 1.06 | 1.37 | 0.36 | 0.40 | 0.81 | 1.20 | 0.88 | 1.20 | 0.71 | 1.24 | 0.84 | 0.56 | 0.91 | 1.11 | 1.00 | 1.22 | 1.06 | 1.09 | 0.71 | 0.79 |
| 1980 | 0.83 | 1.28 | 0.59 | 0.70 | 0.89 | 1.20 | 0.66 | 1.09 | 0.75 | 1.15 | 0.69 | 0.46 | 0.95 | 1.22 | 0.98 | 1.28 | 1.04 | 1.02 | 0.74 | 1.07 |
| 1981 | 0.54 | 0.55 | 0.29 | 0.29 | 0.99 | 1.31 | 0.82 | 1.25 | 0.13 | 0.44 | 0.54 | 0.31 | 1.08 | 1.45 | 1.01 | 1.53 | 1.25 | 1.26 | 0.52 | 0.99 |
| 1982 | 0.57 | 0.53 | 0.50 | 0.35 | 0.90 | 1.25 | 0.89 | 1.35 |  |  |  |  | 1.08 | 1.62 | 1.06 | 1.53 | 1.48 | 1.47 |  |  |
| 1983 | 0.85 | 0.30 | 0.59 | 0.01 | 0.49 | 0.63 | 0.68 | 0.84 |  |  |  |  | 1.07 | 1.63 | 0.99 | 1.31 | 1.61 | 1.64 |  |  |
| 1984 | 1.21 | 0.56 | 1.11 | 0.00 | 0.31 | 0.31 | 0.39 | 0.21 |  |  |  |  | 1.21 | 1.61 | 1.03 | 1.30 | 1.28 | 1.44 |  |  |
| 1985 | 0.98 | 0.24 | 2.00 | 0.18 | 0.35 | 0.15 | 0.62 | 0.37 |  |  |  |  | 0.89 | 1.43 | 1.01 | 1.05 | 1.23 | 1.30 |  |  |
| 1986 | 1.06 | 0.18 | 2.56 | 0.52 | 0.50 | 0.26 | 0.75 | 0.39 |  |  |  |  | 0.43 | 1.14 | 0.73 | 0.51 | 0.73 | 1.05 |  |  |
| 1987 | 1.24 | 0.95 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

# APPENDIX B

## BASAL AREA AND STEMS PER HECTARE

## BY SPECIES AND DBH SIZE CLASS

Site IDs correspond to site names listed in Table 2. Notice that only stems larger than 5 cm were inventoried. Species abbreviations are as follows:

PSME = *Pseudotsuga menziesii*
ABCO = *Abies concolor*
ABLA = *Abies lasiocarpa*
PIEN = *Picea engelmannii*
PIPU = *Picea pungens*
PIPO = *Pinus ponderosa*
PIFL = *Pinus flexilis*
PIAR = *Pinus aristata*
POTR = *Populus tremuloides*
ACGL = *Acer glabrum*
QUGA = *Quercus gambelii*
UNKN = unknown species (Generally, these were dead budworm host species.)

Appendix B1. Basal area (sq. m / ha) by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| PEW | PSME | 0.38 | 1.53 | 6.13 | 4.59 | 4.59 | 3.83 | 2.68 | 2.68 | 26.41 |
| PEW | ABCO | 1.15 | 1.53 | 4.59 | 3.44 | 2.3 | 1.15 | 1.53 | 0 | 15.69 |
| PEW | PIEN | 0 | 0.38 | 0.38 | 0 | 0 | 0 | 0 | 0 | 0.76 |
| PEW | PIPU | 0.38 | 0.38 | 1.53 | 1.53 | 1.15 | 0.38 | 0.76 | 0.38 | 6.49 |
| PEW | PIPO | 0 | 0 | 0 | 0.38 | 0 | 0 | 0 | 0 | 0.38 |
| PEW | PIFL | 0.38 | 0.76 | 0.76 | 0.38 | 0 | 0 | 0 | 0 | 2.28 |
| PEW | POTR | 0.77 | 2.3 | 3.06 | 4.59 | 1.92 | 0 | 0 | 0 | 12.64 |
| PEW | ACGL | 0.38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.38 |
| PEW | UNKN | 0 | 0 | 0 | 0 | 0.38 | 0 | 0 | 0 | 0.38 |
| | TOTALS: | 3.44 | 6.88 | 16.45 | 14.91 | 10.34 | 5.36 | 4.97 | 3.06 | 65.41 |
| PEH | PSME | 0.76 | 0.96 | 2.68 | 2.68 | 1.54 | 1.53 | 1.91 | 0.57 | 12.63 |
| PEH | ABCO | 0 | 2.49 | 2.49 | 1.54 | 1.34 | 1.34 | 0.38 | 0.19 | 9.77 |
| PEH | PIEN | 0.96 | 5.55 | 4.97 | 4.59 | 2.68 | 1.92 | 0.19 | 0.19 | 21.05 |
| PEH | PIPU | 0 | 0 | 0.96 | 0.95 | 0.19 | 0.19 | 0 | 0 | 2.29 |
| PEH | PIPO | 0 | 0 | 0.19 | 0 | 0 | 0 | 0 | 0 | 0.19 |
| PEH | PIFL | 0 | 0.19 | 0.38 | 0.57 | 0.19 | 0 | 0 | 0 | 1.33 |
| PEH | POTR | 0.76 | 0.96 | 5.55 | 0.38 | 0 | 0 | 0 | 0 | 7.65 |
| PEH | ACGL | 0.57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.57 |
| | TOTALS: | 3.05 | 10.15 | 17.22 | 10.71 | 5.94 | 4.98 | 2.48 | 0.95 | 55.48 |
| WVA | PSME | 3.42 | 1.23 | 1.42 | 0.49 | 1.46 | 0 | 0 | 0 | 8.02 |
| WVA | ABCO | 2 | 2.11 | 0.74 | 0.33 | 0.16 | 0 | 0 | 0 | 5.34 |
| WVA | PIPO | 1.21 | 4.33 | 2.05 | 3.8 | 1.56 | 0 | 0 | 0 | 12.95 |
| WVA | UNKN | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.16 |
| | TOTALS: | 6.79 | 7.67 | 4.21 | 4.62 | 3.18 | 0 | 0 | 0 | 26.47 |
| FRC | PSME | 2 | 2.33 | 1.33 | 3.33 | 8.67 | 6.66 | 5 | 4.67 | 33.99 |
| FRC | ABCO | 6 | 1.66 | 2.66 | 1 | 2.66 | 0.67 | 3.33 | 2.33 | 20.31 |
| FRC | PIPO | 1 | 0.66 | 1.34 | 1.67 | 3 | 4 | 1.33 | 0.67 | 13.67 |
| FRC | PIFL | 0.66 | 0.33 | 0 | 0 | 0.66 | 0.33 | 0 | 0 | 1.98 |
| FRC | POTR | 0.67 | 1.67 | 0.66 | 0.33 | 0 | 0 | 0 | 0 | 3.33 |
| | TOTALS: | 10.33 | 6.65 | 5.99 | 6.33 | 14.99 | 11.66 | 9.66 | 7.67 | 73.28 |
| LGR | PSME | 3.06 | 8.42 | 13.58 | 10.53 | 0.77 | 0 | 0.19 | 0 | 36.55 |
| LGR | ABCO | 0.19 | 0 | 0 | 0.38 | 0 | 0 | 0 | 0 | 0.57 |
| LGR | PIEN | 0.38 | 0 | 0.19 | 0 | 0 | 0 | 0 | 0 | 0.57 |
| LGR | POTR | 3.45 | 3.07 | 0 | 0 | 0 | 0 | 0 | 0 | 6.52 |
| LGR | UNKN | 0 | 0.38 | 0.19 | 0 | 0 | 0 | 0 | 0 | 0.57 |
| | TOTALS: | 7.08 | 11.87 | 13.96 | 10.91 | 0.77 | 0 | 0.19 | 0 | 44.78 |

Appendix B1. Basal area (sq. m / ha) by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| LOG | PSME | 1.72 | 3.45 | 4.02 | 0 | 0 | 0 | 0 | 0 | 9.19 |
| LOG | ABCO | 0.19 | 0.95 | 0 | 0 | 0 | 0 | 0 | 0 | 1.14 |
| LOG | PIPO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LOG | POTR | 2.3 | 4.78 | 0.58 | 0 | 0 | 0 | 0 | 0 | 7.66 |
| LOG | UNKN | 0 | 0.38 | 0 | 0 | 0 | 0 | 0 | 0 | 0.38 |
|  | TOTALS: | 4.21 | 9.56 | 4.6 | 0 | 0 | 0 | 0 | 0 | 18.37 |
| FNL | PSME | 4.98 | 12.82 | 13.39 | 4.02 | 0 | 0 | 0 | 0 | 35.21 |
| FNL | ABCO | 0.58 | 0.76 | 0.19 | 0.19 | 0 | 0 | 0 | 0 | 1.72 |
| FNL | PIPO | 0.38 | 0.76 | 1.16 | 0 | 0 | 0 | 0 | 0 | 2.3 |
| FNL | PIFL | 0 | 0.57 | 0 | 0 | 0 | 0 | 0 | 0 | 0.57 |
| FNL | POTR | 0.57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.57 |
| FNL | UNKN | 0 | 0.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0.76 |
|  | TOTALS: | 6.51 | 15.67 | 14.74 | 4.21 | 0 | 0 | 0 | 0 | 41.13 |
| EFK | PSME | 1.34 | 6.33 | 10.77 | 12.05 | 3.26 | 0 | 0 | 0 | 33.75 |
| EFK | ABCO | 0.66 | 1.34 | 0 | 0.92 | 0 | 0 | 0 | 0 | 2.92 |
| EFK | PIEN | 0 | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 |
| EFK | PIPU | 1.67 | 2.34 | 2 | 1.34 | 0.67 | 0 | 0 | 0 | 8.02 |
| EFK | PIPO | 0 | 0 | 0.66 | 0.59 | 0 | 0 | 0 | 0 | 1.25 |
| EFK | PIFL | 0 | 0 | 0 | 0.33 | 0 | 0 | 0 | 0 | 0.33 |
| EFK | POTR | 0.67 | 1.67 | 1.33 | 0 | 0 | 0 | 0 | 0 | 3.67 |
|  | TOTALS: | 4.34 | 12.01 | 14.76 | 15.23 | 3.93 | 0 | 0 | 0 | 50.27 |
| LEF | PSME | 2.67 | 4.33 | 4.43 | 1.7 | 2.63 | 2.85 | 0.92 | 2.29 | 21.82 |
| LEF | ABCO | 1.82 | 3.55 | 2.92 | 7.28 | 2.11 | 0.85 | 1 | 0 | 19.53 |
| LEF | PIPU | 0.33 | 2 | 0.33 | 0.33 | 0.66 | 0.33 | 0 | 0 | 3.98 |
| LEF | PIPO | 0.59 | 0 | 0.67 | 0 | 0.52 | 0.93 | 1.04 | 2.32 | 6.07 |
| LEF | QUGA | 0 | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 0.33 |
|  | TOTALS: | 5.41 | 10.21 | 8.35 | 9.31 | 5.92 | 4.96 | 2.96 | 4.61 | 51.73 |
| BAR | PSME | 0.57 | 0.67 | 0.96 | 1.44 | 0.19 | 0 | 0 | 0 | 3.83 |
| BAR | ABCO | 0.19 | 2.68 | 3.54 | 0.77 | 0.57 | 0 | 0 | 0 | 7.75 |
| BAR | PIPO | 0 | 0.29 | 0.48 | 1.05 | 0.86 | 0 | 0 | 0 | 2.68 |
| BAR | PIFL | 0.1 | 0.29 | 0.19 | 0.1 | 0.19 | 0 | 0 | 0 | 0.87 |
| BAR | POTR | 0.29 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0.39 |
|  | TOTALS: | 1.15 | 4.03 | 5.17 | 3.36 | 1.81 | 0 | 0 | 0 | 15.52 |

Appendix B1. Basal area (sq. m / ha) by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BON | PSME | 4.21 | 4.02 | 4.02 | 6.03 | 0 | 0 | 0 | 0 | 18.28 |
| BON | ABCO | 0 | 0.38 | 0 | 0 | 0 | 0 | 0 | 0 | 0.38 |
| BON | ABLA | 0.67 | 0.57 | 0.38 | 0.48 | 0 | 0 | 0 | 0 | 2.1 |
| BON | PIEN | 1.24 | 2.21 | 1.34 | 1.05 | 0 | 0 | 0 | 0 | 5.84 |
| BON | PIPU | 0.76 | 0.19 | 0.19 | 0 | 0 | 0 | 0 | 0 | 1.14 |
| BON | POTR | 0.58 | 1.15 | 0.1 | 0 | 0 | 0 | 0 | 0 | 1.83 |
|  | TOTALS: | 7.46 | 8.52 | 6.03 | 7.56 | 0 | 0 | 0 | 0 | 29.57 |
| SRR | PSME | 0.69 | 1.9 | 2.53 | 0.57 | 0 | 0 | 0 | 0 | 5.69 |
| SRR | ABCO | 7.46 | 12.5 | 4.4 | 1.13 | 0 | 0 | 0 | 0 | 25.49 |
| SRR | PIPO | 0.54 | 0.63 | 0.19 | 0.19 | 0 | 0 | 0 | 0 | 1.55 |
| SRR | PIFL | 1.88 | 0.96 | 0.13 | 0 | 0 | 0 | 0 | 0 | 2.97 |
| SRR | UNKN | 0 | 0 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0.08 |
|  | TOTALS: | 10.57 | 15.99 | 7.33 | 1.89 | 0 | 0 | 0 | 0 | 35.78 |
| RTC | PSME | 13.9 | 9.38 | 6.1 | 6.74 | 5.04 | 2.03 | 0.59 | 0 | 43.78 |
| RTC | ABCO | 0.33 | 0.33 | 0.85 | 1.33 | 1 | 0 | 0 | 0 | 3.84 |
| RTC | PIEN | 1.19 | 0.94 | 0.19 | 0 | 0 | 0 | 0 | 0 | 2.32 |
| RTC | PIFL | 0.59 | 0.66 | 0 | 0 | 0.26 | 0 | 0 | 0 | 1.51 |
| RTC | POTR | 3.02 | 0.33 | 0 | 0 | 0 | 0 | 0 | 0 | 3.35 |
|  | TOTALS: | 19.03 | 11.64 | 7.14 | 8.07 | 6.3 | 2.03 | 0.59 | 0 | 54.8 |
| FWN | PSME | 2.14 | 3.83 | 5.58 | 2.81 | 0.25 | 0 | 0 | 0 | 14.61 |
| FWN | ABCO | 0.42 | 0.6 | 1.34 | 0.63 | 0 | 0 | 0 | 0 | 2.99 |
| FWN | PIPO | 0.08 | 0 | 0.17 | 0.25 | 0 | 0 | 0 | 0 | 0.5 |
| FWN | PIFL | 0.84 | 1.8 | 0.39 | 0.58 | 0 | 0 | 0 | 0 | 3.61 |
| FWN | POTR | 0.67 | 0.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0.75 |
|  | TOTALS: | 4.15 | 6.31 | 7.48 | 4.27 | 0.25 | 0 | 0 | 0 | 22.46 |
| RED | PSME | 5.09 | 5.58 | 3.92 | 0.41 | 0.41 | 0.17 | 0 | 0 | 15.58 |
| RED | ABCO | 3.17 | 6.75 | 3.58 | 1.83 | 0.42 | 0 | 0 | 0 | 15.75 |
| RED | PIEN | 0.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.17 |
| RED | PIPU | 0 | 0 | 0 | 0.17 | 0 | 0 | 0 | 0 | 0.17 |
| RED | PIPO | 0.17 | 0.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0.34 |
| RED | PIFL | 0.17 | 0.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0.34 |
| RED | POTR | 1.58 | 0.17 | 0 | 0 | 0 | 0 | 0 | 0 | 1.75 |
| RED | UNKN | 0.34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.34 |
|  | TOTALS: | 10.69 | 12.84 | 7.5 | 2.41 | 0.83 | 0.17 | 0 | 0 | 34.44 |

Appendix B1. Basal area (sq. m / ha) by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| POL | PSME | 1.72 | 3.15 | 7.66 | 7.37 | 3.06 | 2.78 | 0.86 | 0.29 | 26.89 |
| POL | ABCO | 0.1 | 0.57 | 0.96 | 1.34 | 0.67 | 0.1 | 0 | 0 | 3.74 |
| POL | PIPU | 0 | 0.67 | 1.81 | 0.76 | 0.67 | 0.1 | 0 | 0 | 4.01 |
| POL | PIPO | 0 | 0 | 0 | 0.38 | 0 | 0 | 0 | 0 | 0.38 |
| POL | PIFL | 0.1 | 0.77 | 0.1 | 0.38 | 0.38 | 0 | 0 | 0 | 1.73 |
| POL | PIAR | 0 | 0.19 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 |
|  | TOTALS: | 1.92 | 5.35 | 10.53 | 10.23 | 4.78 | 2.98 | 0.86 | 0.29 | 36.94 |
| FLE | PSME | 3.55 | 6.22 | 6.51 | 2.96 | 0.86 | 0.29 | 0.1 | 0 | 20.49 |
| FLE | ABCO | 0.58 | 2.49 | 2.68 | 1.25 | 1.44 | 0.38 | 0.1 | 0 | 8.92 |
| FLE | PIPO | 0 | 0 | 0.19 | 0.38 | 0 | 0 | 0 | 0 | 0.57 |
| FLE | POTR | 2.29 | 2.01 | 0 | 0 | 0 | 0 | 0 | 0 | 4.3 |
| FLE | UNKN | 0.38 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0.48 |
|  | TOTALS: | 6.8 | 10.72 | 9.38 | 4.69 | 2.3 | 0.67 | 0.2 | 0 | 34.76 |
| ALA | PSME | 0.57 | 3.45 | 8.8 | 14.35 | 11.1 | 8.04 | 2.87 | 2.68 | 51.86 |
| ALA | ABCO | 0 | 0.19 | 0.96 | 1.34 | 0.38 | 0.57 | 0 | 0 | 3.44 |
| ALA | PIEN | 0 | 0.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0.95 |
| ALA | PIFL | 0 | 0 | 0.38 | 0 | 0 | 0 | 0 | 0 | 0.38 |
| ALA | POTR | 0.19 | 1.15 | 1.53 | 0.77 | 0 | 0 | 0 | 0 | 3.64 |
| ALA | UNKN | 0 | 0 | 0 | 0.19 | 0 | 0 | 0 | 0 | 0.19 |
|  | TOTALS: | 0.76 | 5.74 | 11.67 | 16.65 | 11.48 | 8.61 | 2.87 | 2.68 | 60.46 |
| ALW | PSME | 1.04 | 1.55 | 4.94 | 8.82 | 6.98 | 4.84 | 1.15 | 2.47 | 31.79 |
| ALW | ABCO | 0 | 0.76 | 0 | 0 | 0.76 | 0 | 0 | 0 | 1.52 |
| ALW | ABLA | 1.33 | 2.2 | 0.66 | 0 | 0 | 0 | 0 | 0 | 4.19 |
| ALW | PIEN | 0 | 0.84 | 0.38 | 0.56 | 0.56 | 0 | 0 | 0 | 2.34 |
| ALW | POTR | 0 | 3.24 | 2.35 | 1.68 | 0 | 0 | 0 | 0 | 7.27 |
|  | TOTALS: | 2.37 | 8.59 | 8.33 | 11.06 | 8.3 | 4.84 | 1.15 | 2.47 | 47.11 |
| LAJ | PSME | 0 | 0.38 | 0.48 | 0.77 | 1.73 | 2.01 | 1.05 | 1.34 | 7.76 |
| LAJ | ABCO | 0 | 0 | 0.77 | 0.1 | 0.19 | 0.19 | 0.29 | 0.29 | 1.83 |
| LAJ | PIPU | 0.1 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | 0.2 |
| LAJ | PIPO | 0.1 | 0.77 | 2.29 | 1.43 | 0.96 | 3.92 | 0.96 | 0.48 | 10.91 |
| LAJ | PIFL | 0.2 | 0.2 | 0.19 | 0.48 | 0 | 0 | 0.19 | 0 | 1.26 |
| LAJ | PIAR | 0 | 0 | 0 | 0.19 | 0 | 0 | 0 | 0 | 0.19 |
|  | TOTALS: | 0.4 | 1.35 | 3.73 | 3.07 | 2.88 | 6.12 | 2.49 | 2.11 | 22.15 |

Appendix B2. Stems per hectare by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| PEW | PSME | 15 | 26 | 57 | 28 | 20 | 11 | 6 | 5 | 169 |
| PEW | ABCO | 55 | 28 | 50 | 22 | 10 | 3 | 4 | 0 | 171 |
| PEW | PIEN | 0 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 10 |
| PEW | PIPU | 23 | 8 | 15 | 9 | 5 | 1 | 2 | 1 | 64 |
| PEW | PIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| PEW | PIFL | 14 | 18 | 8 | 3 | 0 | 0 | 0 | 0 | 43 |
| PEW | POTR | 28 | 46 | 32 | 28 | 8 | 0 | 0 | 0 | 142 |
| PEW | ACGL | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| PEW | UNKN | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| | TOTALS: | 163 | 132 | 165 | 92 | 45 | 16 | 12 | 5 | 629 |
| | | | | | | | | | | |
| PEH | PSME | 46 | 17 | 27 | 16 | 7 | 4 | 4 | 1 | 123 |
| PEH | ABCO | 0 | 40 | 24 | 10 | 6 | 4 | 1 | 0 | 85 |
| PEH | PIEN | 43 | 110 | 58 | 29 | 12 | 6 | 0 | 0 | 257 |
| PEH | PIPU | 0 | 0 | 11 | 6 | 1 | 1 | 0 | 0 | 18 |
| PEH | PIPO | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| PEH | PIFL | 0 | 3 | 4 | 4 | 1 | 0 | 0 | 0 | 12 |
| PEH | POTR | 36 | 17 | 60 | 2 | 0 | 0 | 0 | 0 | 115 |
| PEH | ACGL | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 |
| | TOTALS: | 160 | 187 | 186 | 67 | 26 | 15 | 6 | 2 | 649 |
| | | | | | | | | | | |
| WVA | PSME | 187 | 25 | 15 | 3 | 6 | 0 | 0 | 0 | 236 |
| WVA | ABCO | 96 | 46 | 9 | 2 | 1 | 0 | 0 | 0 | 154 |
| WVA | PIPO | 62 | 92 | 22 | 25 | 7 | 0 | 0 | 0 | 208 |
| WVA | UNKN | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| | TOTALS: | 359 | 163 | 46 | 30 | 14 | 0 | 0 | 0 | 612 |
| | | | | | | | | | | |
| FRC | PSME | 115 | 47 | 14 | 21 | 36 | 21 | 12 | 8 | 274 |
| FRC | ABCO | 405 | 40 | 32 | 7 | 11 | 2 | 8 | 4 | 507 |
| FRC | PIPO | 74 | 13 | 14 | 10 | 13 | 12 | 3 | 1 | 139 |
| FRC | PIFL | 51 | 6 | 0 | 0 | 3 | 1 | 0 | 0 | 60 |
| FRC | POTR | 26 | 36 | 8 | 2 | 0 | 0 | 0 | 0 | 72 |
| | TOTALS: | 671 | 141 | 68 | 40 | 62 | 36 | 23 | 13 | 1052 |
| | | | | | | | | | | |
| LGR | PSME | 141 | 157 | 146 | 69 | 4 | 0 | 0 | 0 | 517 |
| LGR | ABCO | 8 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 11 |
| LGR | PIEN | 13 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 16 |
| LGR | POTR | 157 | 73 | 0 | 0 | 0 | 0 | 0 | 0 | 230 |
| LGR | UNKN | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 10 |
| | TOTALS: | 318 | 238 | 150 | 72 | 4 | 0 | 0 | 0 | 783 |

Appendix B2. Stems per hectare by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| LOG | PSME | 76 | 65 | 48 | 0 | 0 | 0 | 0 | 0 | 188 |
| LOG | ABCO | 7 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| LOG | PIPO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| LOG | POTR | 94 | 105 | 7 | 0 | 0 | 0 | 0 | 0 | 207 |
| LOG | UNKN | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
|  | TOTALS: | 177 | 199 | 55 | 0 | 0 | 0 | 0 | 0 | 431 |
| FNL | PSME | 253 | 275 | 144 | 27 | 0 | 0 | 0 | 0 | 699 |
| FNL | ABCO | 20 | 15 | 2 | 1 | 0 | 0 | 0 | 0 | 39 |
| FNL | PIPO | 14 | 17 | 13 | 0 | 0 | 0 | 0 | 0 | 43 |
| FNL | PIFL | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| FNL | POTR | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| FNL | UNKN | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
|  | TOTALS: | 314 | 334 | 158 | 28 | 0 | 0 | 0 | 0 | 834 |
| EFK | PSME | 83 | 128 | 110 | 77 | 15 | 0 | 0 | 0 | 413 |
| EFK | ABCO | 39 | 31 | 0 | 7 | 0 | 0 | 0 | 0 | 77 |
| EFK | PIEN | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| EFK | PIPU | 97 | 50 | 24 | 9 | 3 | 0 | 0 | 0 | 182 |
| EFK | PIPO | 0 | 0 | 6 | 4 | 0 | 0 | 0 | 0 | 11 |
| EFK | PIFL | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| EFK | POTR | 27 | 34 | 15 | 0 | 0 | 0 | 0 | 0 | 76 |
|  | TOTALS: | 246 | 248 | 155 | 98 | 18 | 0 | 0 | 0 | 765 |
| LEF | PSME | 135 | 88 | 44 | 11 | 11 | 9 | 2 | 4 | 305 |
| LEF | ABCO | 91 | 71 | 31 | 46 | 9 | 3 | 2 | 0 | 252 |
| LEF | PIPU | 12 | 40 | 4 | 2 | 3 | 1 | 0 | 0 | 62 |
| LEF | PIPO | 69 | 0 | 6 | 0 | 2 | 3 | 2 | 4 | 86 |
| LEF | QUGA | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
|  | TOTALS: | 306 | 209 | 85 | 59 | 26 | 16 | 7 | 8 | 715 |
| BAR | PSME | 29 | 14 | 9 | 9 | 1 | 0 | 0 | 0 | 62 |
| BAR | ABCO | 7 | 53 | 37 | 5 | 2 | 0 | 0 | 0 | 104 |
| BAR | PIPO | 0 | 6 | 6 | 6 | 4 | 0 | 0 | 0 | 21 |
| BAR | PIFL | 7 | 5 | 2 | 1 | 1 | 0 | 0 | 0 | 15 |
| BAR | POTR | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
|  | TOTALS: | 55 | 79 | 54 | 20 | 8 | 0 | 0 | 0 | 216 |

Appendix B2. Stems per hectare by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| BON | PSME | 211 | 89 | 44 | 37 | 0 | 0 | 0 | 0 | 381 |
| BON | ABCO | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| BON | ABLA | 37 | 12 | 4 | 3 | 0 | 0 | 0 | 0 | 57 |
| BON | PIEN | 53 | 45 | 16 | 7 | 0 | 0 | 0 | 0 | 121 |
| BON | PIPU | 42 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 48 |
| BON | POTR | 41 | 28 | 1 | 0 | 0 | 0 | 0 | 0 | 70 |
|  | TOTALS: | 384 | 185 | 68 | 47 | 0 | 0 | 0 | 0 | 685 |
| SRR | PSME | 31 | 40 | 29 | 4 | 0 | 0 | 0 | 0 | 104 |
| SRR | ABCO | 365 | 272 | 50 | 8 | 0 | 0 | 0 | 0 | 695 |
| SRR | PIPO | 25 | 13 | 3 | 1 | 0 | 0 | 0 | 0 | 42 |
| SRR | PIFL | 82 | 23 | 1 | 0 | 0 | 0 | 0 | 0 | 106 |
| SRR | UNKN | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
|  | TOTALS: | 503 | 348 | 84 | 13 | 0 | 0 | 0 | 0 | 947 |
| RTC | PSME | 939 | 197 | 66 | 42 | 22 | 6 | 1 | 0 | 1274 |
| RTC | ABCO | 19 | 9 | 8 | 9 | 5 | 0 | 0 | 0 | 50 |
| RTC | PIEN | 143 | 20 | 2 | 0 | 0 | 0 | 0 | 0 | 165 |
| RTC | PIFL | 28 | 14 | 0 | 0 | 1 | 0 | 0 | 0 | 43 |
| RTC | POTR | 274 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 279 |
|  | TOTALS: | 1404 | 245 | 76 | 51 | 28 | 6 | 1 | 0 | 1811 |
| FWN | PSME | 116 | 80 | 60 | 18 | 1 | 0 | 0 | 0 | 275 |
| FWN | ABCO | 16 | 14 | 14 | 4 | 0 | 0 | 0 | 0 | 48 |
| FWN | PIPO | 6 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 10 |
| FWN | PIFL | 35 | 38 | 5 | 4 | 0 | 0 | 0 | 0 | 82 |
| FWN | POTR | 31 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 34 |
|  | TOTALS: | 203 | 135 | 81 | 28 | 1 | 0 | 0 | 0 | 449 |
| RED | PSME | 261 | 113 | 44 | 3 | 2 | 1 | 0 | 0 | 423 |
| RED | ABCO | 135 | 148 | 39 | 12 | 2 | 0 | 0 | 0 | 336 |
| RED | PIEN | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| RED | PIPU | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| RED | PIPO | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| RED | PIFL | 13 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
| RED | POTR | 105 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 110 |
| RED | UNKN | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 |
|  | TOTALS: | 557 | 273 | 83 | 16 | 4 | 1 | 0 | 0 | 932 |

Appendix B2. Stems per hectare by species and dbh size class (cm).

| SITE ID | SPECIES | 5-20 | 21-30 | 31-40 | 41-50 | 51-60 | 61-70 | 71-80 | > 80 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| POL | PSME | 73 | 69 | 78 | 47 | 13 | 8 | 2 | 0 | 290 |
| POL | ABCO | 3 | 11 | 9 | 8 | 3 | 0 | 0 | 0 | 34 |
| POL | PIPU | 0 | 11 | 21 | 6 | 3 | 0 | 0 | 0 | 41 |
| POL | PIPO | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| POL | PIFL | 5 | 14 | 1 | 3 | 1 | 0 | 0 | 0 | 25 |
| POL | PIAR | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
|  | TOTALS: | 81 | 109 | 109 | 66 | 20 | 9 | 2 | 0 | 396 |
| FLE | PSME | 129 | 126 | 68 | 19 | 3 | 1 | 0 | 0 | 347 |
| FLE | ABCO | 22 | 49 | 27 | 7 | 6 | 1 | 0 | 0 | 113 |
| FLE | PIPO | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 5 |
| FLE | POTR | 136 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 185 |
| FLE | UNKN | 13 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 14 |
|  | TOTALS: | 301 | 225 | 97 | 30 | 9 | 2 | 0 | 0 | 665 |
| ALA | PSME | 27 | 72 | 89 | 90 | 47 | 25 | 6 | 5 | 363 |
| ALA | ABCO | 0 | 4 | 10 | 8 | 2 | 2 | 0 | 0 | 25 |
| ALA | PIEN | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| ALA | PIFL | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| ALA | POTR | 7 | 21 | 18 | 6 | 0 | 0 | 0 | 0 | 52 |
| ALA | UNKN | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
|  | TOTALS: | 34 | 119 | 122 | 105 | 49 | 27 | 6 | 5 | 467 |
| ALW | PSME | 75 | 31 | 50 | 56 | 31 | 15 | 3 | 4 | 264 |
| ALW | ABCO | 0 | 18 | 0 | 0 | 3 | 0 | 0 | 0 | 21 |
| ALW | ABLA | 171 | 44 | 8 | 0 | 0 | 0 | 0 | 0 | 223 |
| ALW | PIEN | 0 | 17 | 5 | 4 | 3 | 0 | 0 | 0 | 29 |
| ALW | POTR | 0 | 71 | 24 | 11 | 0 | 0 | 0 | 0 | 106 |
|  | TOTALS: | 246 | 182 | 86 | 71 | 37 | 15 | 3 | 4 | 643 |
| LAJ | PSME | 0 | 9 | 4 | 5 | 7 | 6 | 2 | 2 | 35 |
| LAJ | ABCO | 0 | 0 | 8 | 1 | 1 | 1 | 1 | 1 | 11 |
| LAJ | PIPU | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 4 |
| LAJ | PIPO | 4 | 14 | 25 | 9 | 4 | 12 | 2 | 1 | 71 |
| LAJ | PIFL | 12 | 4 | 2 | 3 | 0 | 0 | 0 | 0 | 21 |
| LAJ | PIAR | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
|  | TOTALS: | 20 | 26 | 38 | 19 | 12 | 19 | 6 | 4 | 143 |